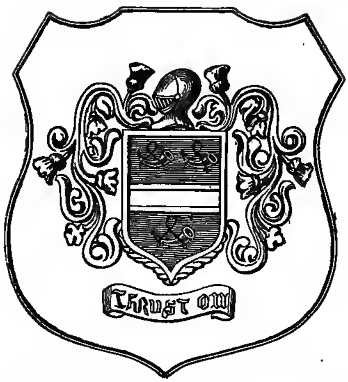
THRUST ON

INTERNATIONAL ENGINEERING CONGRESS
(GLASGOW), 1901.

REPORT OF THE PROCEEDINGS
AND
ABSTRACTS
OF THE PAPERS READ.

WITH A PREFACE

BY ROBERT CAIRD, LL.D.,
Chairman of the Executive Committee.

Edited by the General Secretary, J. D. CORMACK.

GLASGOW:
WILLIAM ASHER, 128 RENFIELD STREET.
1902.

CONTENTS.

PREFACE.

The Executive Committee desires to seize the opportunity of the issue of the Report and Abstracts to express its deep sense of indebtedness to the many Institutions, Societies, and gentlemen who contributed to make the Congress of 1901 the great success it undoubtedly was.

The idea of holding the Congress originated with the Council of the Institution of Engineers and Shipbuilders in Scotland; which, considering that the Exhibition would furnish an excellent occasion for ensuring the attendance of a large number of engineers from all over the world in Glasgow, during 1901, appointed a small committee from among the members of that Institution, consisting of Dr. Barr and Messrs. Biggart, MacIntosh, Mavor, and myself, to study and report upon the best means of giving effect to the project.

We consulted the office-bearers and officials of the leading engineering societies in Britain, and received most valuable advice, information, and suggestions from them.

The Institution of Civil Engineers in particular rendered us invaluable assistance. The first notice given publicly of the intention to hold a Congress was by the then President of the Institution of Civil Engineers, Sir William Preece, in his Introductory Address at the opening of the summer meeting in London in 1899. His successor, Sir Douglas Fox, consented to act as Chairman of our London Committee, and in that capacity materially contributed towards the formation of our executive organisation. Dr. Tudsbery also acted as Secretary of that Committee, and in innumerable ways assisted us with advice, which, in view of his vast experience, was of the utmost value. And yet another President of the Institution of Civil Engineers, Mr. Mansergh, accepted nomination as President of the Congress, delivered an address at the opening of the proceedings, received the delegates of Foreign Governments and

Societies, and was present throughout the sittings and entertainments. Further, two past Presidents of that great Institution, Sir Benjamin Baker and Sir John Wolfe Barry, presided over Sections I. and II., assisted as secretaries by Mr. R. Elliot-Cooper and Professor L. F. Vernon Harcourt.

The work of each of the remaining seven sections was undertaken by the leading British Society devoted to the particular branch of Engineering with which it dealt. Most of these Societies have at their own expense published full reports of the proceedings in their several departments as a part of their ordinary transactions. The proceedings of Sections I. and II. only have been published by the Congress, a sum of £500 having been granted by the Institution of Civil Engineers towards the expenses of this publication.

The Committee fully and gratefully appreciates the extent to which its labours and responsibilities have been lightened and relieved by the generous co-operation of these Institutions and Societies whose names appear in their due place in the Report and Abstracts.

In the course of negotiation it soon became apparent that the numbers attending the Congress would considerably exceed the original estimate, and that extraordinary measures would have to be taken for the accommodation of members. An appeal was made to the members of the Institution of Engineers and Shipbuilders in Scotland and their friends to extend hospitality to our guests, with such good results that, notwithstanding the apprehensions of some of the most experienced organisers of summer meetings whom we consulted, no difficulty was encountered in suitably housing the members. The thanks of the Committee are due not only to the sub-committee which took charge of accommodation, but also to those gentlemen of Glasgow and the West of Scotland who placed their houses at our disposal.

We desire also to acknowledge our indebtedness to the Lord Provost and Corporation of the City of Glasgow for the countenance they gave to the Congress officially, and for the magnificent and imposing reception they accorded to the Foreign Delegates and

Members of the Congress, a reception which, in the opinion of many of those gentlemen, compared favourably with similar entertainments in the capitals of Europe under Royal auspices. And the University Buildings in which the meetings were held proved an ideal set of surroundings for such a gathering and lent a dignity to the proceedings for which we cannot be too grateful to the University Court.

It is impossible adequately to express our thanks to all those agencies which enabled us to carry our scheme to a successful termination. Among those we wish specially to name are the Executive of the Glasgow International Exhibition; the various Railway Companies which gave unusual facilities to members; the Steamship Companies and owners who assisted in the organising of Excursions; and the Firms which opened their works to the inspection of visiting engineers.

Readers of these Abstracts will certainly join in according a very hearty vote of thanks to the Honorary Secretaries of the various Sections, and more particularly to Professor J. D. Cormack, the editor of all the general publications and the General Secretary of the Congress, to whose untiring energy, great administrative ability, admirable tact and geniality the smooth working of the whole organisation is chiefly due.

In conclusion, it has been a source of great pleasure to the Executive Committee to hear, as it has heard from many of our foreign guests, that the arrangements made for their comfort and entertainment have been thoroughly appreciated, and that they have derived both pleasure and profit from their visit to their confrères in Glasgow in 1901.

R. CAIRD.

OFFICE-BEARERS.

Honorary President.

The Right Honourable the Lord Kelvin, G.C.V.O.

Honorary Vice-Presidents.

The Most Noble the Duke of Argyle, K.T.
The Most Noble the Duke of Fife, K.T.
The Right Honourable the Earl of Elgin, K.G.
The Right Honourable the Lord Balfour of Burleigh, K.T.
The Right Honourable the Lord Blythswood.
The Right Honourable the Lord Provost of Edinburgh, (James Steel).
The Honourable the Lord Provost of Glasgow, (Samuel Chisholm, LL.D.).

President.

James Mansergh, F.R.S., President of the Institution of Civil Engineers.

Vice-Presidents.

The Right Hon. the Earl of Glasgow, G.C.M.G., President of the Institution of Naval Architects.
William H. Maw, President of the Institution of Mechanical Engineers.
William Whitwell, President of the Iron and Steel Institute.
Professor John Perry, D.Sc., F.R.S., Past President of the Institution of Electrical Engineers.
Sir William Thomas Lewis, Bart., President of the Institution of Mining Engineers.
Robert Caird, LL.D., Past President of the Institution of Engineers and Shipbuilders in Scotland.
Colonel J. M. Denny, M.P., President of the Institution of Marine Engineers.
Professor R. L. Weighton, Vice-President of the North-East Coast Institution of Engineers and Shipbuilders.
James S. Dixon, President of the Mining Institute of Scotland.
E. George Mawbey, President of the Incorporated Association of Municipal and County Engineers.
George Livesey, the Institution of Gas Engineers.

General Committee.

Chairman, James Mansergh, F.R.S.

The members of this committee are distinguished by the sign + placed opposite their names in the List of Members, see p. 355 *et seq.*

Reception Committee.

Chairman, Robert Caird, LL.D.

The members of this committee are distinguished by the sign ++ placed opposite their names in the List of Members, see p. 355 *et seq.*

London Committee.

Chairman: Sir Douglas Fox.
Honorary Secretary: J. H. T. Tudsbery, D.Sc.

Sir Frederick Abel, Bart., K.C.B.
Prof. W. Grylls Adams, D.Sc.
James Adamson.
Sir John G. N. Alleyne, Bart.
John A. F. Aspinall.
Professor W. E. Ayrton, F.R.S.
Sir Benjamin Baker, K.C.M.G.
Sir Nathaniel Barnaby, K.C.B.
F. K. Barnes.
Prof. Archibald Barr, D.Sc.
James Barrowman.
Sir John Wolfe Barry, K.C.B.
Sir Lowthian Bell, Bart.
W. H. Bleckly.
Sir Frederick J. Bramwell, Bart.
The Rt. Hon. Lord Brassey, K.C.B.
Bennett H. Brough.
M. Walton Brown.
Sir G. B. Bruce.
James C. Cadman.
Robert Caird, LL.D.
Sir Edward H. Carbutt, Bart.
Major P. Cardew, R.E.
Andrew Carnegie, LL.D.
A. G. Charleton.
Thomas Cole.
R. Elliott Cooper.
S. B. Cottrell.
R. E. Crompton.
Sir David Dale, Bart.
The Rt. Hon. Sir John Dalrymple-Hay, K.C.B.
R. W. Dana, M.A.
Henry Davey.
Maurice Deacon.
James S. Dixon.
Bryan Donkin.
Sir Theodore Doxford, M.P.
James Dunn.
Sir John Durston, K.C.B.
F. Elgar, LL.D.
Prof. Arch. C. Elliott, D.Sc.
Thomas Evens.
J. C. Hawkshaw.
Charles Hawksley.
J. W. Helps.
George C. V. Holmes, M.A.
The Rt. Hon. the Earl of Hopetoun.
John Inglis, LL.D.
S. W. Johnson.
Arthur Keen.
The Rt. Hon. Lord Kelvin, G.C.V.O.
Alex. B. W. Kennedy, LL.D.
Sir James Kitson, Bart., M.P.
W. E. Langdon.
Sir William T. Lewis, Bart.
George T. Livesey.
J. A. Longden.
C. H. Lowe.
W. G. M'Millan.
Sir Henry Mance, C.I.E.
James Mansergh, F.R.S.
E. P. Martin.
H. A. Mavor.
W. H. Maw.
T. W. H. Mitchell.
Henry Morgan.
Arthur Musker.
John Nevin.
Sir Andrew Noble, K.C.B.
Prof. John Perry, D.Sc.
S. R. Platt.
Sir William H. Preece, K.C.B.
Sir Edward G. Reed, K.C.B.
E. Windsor Richards.
Sir Thomas Richardson, M.P.
T. Hurry Riches.
James Riley.
W. C. Roberts.
Sir William Roberts-Austen, K.C.B.
The Rt. Hon. Sir Bernard Samuelson, Bart.
Alexander Siemens.
J. T. Smith.
G. F. Snelus, F.R.S.
C. E. Spagnoletti.
Joseph W. Swan, F.R.S.
James Swinburne.
Prof. Silvanus P. Thomson, F.R.S.
J. I. Thorneycroft, LL.D.
Prof. L. F. Vernon-Harcourt, M.A.

T. M. Favell.
S. Z. de Ferranti.
Prof. G. Carey Foster, F.R.S.
John Gavey.
The Rt. Hon. the Earl of Glasgow, G.C.M.G.
Sir John Glover.
Robert K. Gray.
W. Harpur.
Joseph H. Harrison.
Major-General C. E. Webber, C.B.
Tom Westgarth.
P. G. B. Westmacott.
Sir William H. White, K.C.B.
William Whitwell.
J. H. Wicksteed.
Edward Woods.
Edgar Worthington, B.Sc.
A. F. Yarrow.

Executive Committee.

Chairman: Robert Caird, LL.D.

Sir William Arrol, M.P., LL.D.
Sir Benjamin Baker, K.C.M.G.
*Prof. Archibald Barr, D.Sc.
James Barrowman.
Sir John Wolfe Barry, K.C.B.
*W. Beardmore.
G. T. Beilby.
*A. S. Biggart.
*Prof. J. H. Biles.
Bennett H. Brough.
M. Walton Brown.
Thomas Cole.
R. Elliott Cooper.
W. R. Copland.
R. W. Dana, M.A.
*Archibald Denny.
*James S. Dixon.
Walter Dixon.
Francis Elgar, LL.D.
Thomas Evans.
J. T. Forgie.
*William Foulis.
*Sir Douglas Fox.
J. M. Gale.
The Rt. Hon. the Earl of Glasgow, G.C.M.G.
J. W. Helps.
George C. V. Holmes, M.A.
John Inglis, LL.D.
J. G. Jenkins.
Thos. Kennedy.
W. E. Langdon.
*C. C. Lindsay.
George Livesey.
C. H. Lowe.
*A. B. M'Donald.
*J. F. M'Intosh.
W. G. M'Millan.
E. P. Martin.
William H. Maw.
E. George Mawbey.
*H. A. Mavor.
James Mollison.
R. T. Moore, B.Sc.
*Matthew Paul.
E. Windsor Richards.
Hazleton R. Robson.
*James Rowan.
George Russell.
Alexander Siemens.
John Strain.
*J. H. T. Tudsbery, D.Sc.
Prof. L. F. Vernon-Harcourt, M.A
John Ward.
Prof. W. H. Watkinson.
James Weir.
William Whitwell.
Edgar Worthington, B.Sc.

Local Executive Committee.

Chairman: Robert Caird, LL.D.

* Members of the Executive Committee, whose names are distinguished by an asterisk are members of the Local Executive Committee.

Finance Committee.

Chairman: Robert Caird, LL.D.

James S. Dixon.
Robert Gourlay, LL.D.
James Neilson.
Hugh Reid.
J. R. Richmond.
Paul Rottenburg, LL.D.
Professor Smart, LL.D.

Sub-Committees.

Visits to Works.

SECTION I. (RAILWAYS).—James Brand, David Cooper, W. Lorimer, James Manson, D. A. Matheson, William Melville, Hugh Reid, J. F. Robinson, and R. Elliott Cooper, with J. F. M'Intosh as Convener.

SECTION II. (WATERWAYS AND MARITIME WORKS.)—William M. Alston, W. R. Copland, C. P. Hogg, and Prof. L. F. Vernon-Harcourt, with C. C. Lindsay as Convener.

SECTION III. (MECHANICAL).—Henry Brock, Sinclair Couper, Thomas Kennedy, Prof. W. H. Watkinson, J. D. Young, Thomas Young, and Edgar Worthington, with A. S. Biggart as Convener.

SECTION IV. (NAVAL ARCHITECTURE).—Robert Caird, LL.D., Alexander Gracie, W. J. Luke, James Mollison, and George Holmes, with Prof. J. H. Biles as Convener.

SECTION V. (IRON AND STEEL).—George Beard, William Beardmore, William Clark, David Colville, Walter Dixon, Prof. A. Humboldt Sexton, and Bennett H. Brough, with J. G. Jenkins as Convener.

SECTION VI. (MINING).—J. B. Atkinson, James T. Forgie, T. Lindsay Galloway, James M'Creath, J. M. Ronaldson, Wallace Thorneycroft, and James Barrowman, with James S. Dixon as Convener.

SECTION VII. (MUNICIPAL).—Peter Fyfe, J. M. Gale, Thomas Nisbet, William Paterson, Gilbert Thomson, John Young, and Thomas Cole, with A. B. M'Donald as Convener.

SECTION VIII. (GAS).—G. T. Beilby, G. R. Hislop, and J. W. Helps, with W. Foulis as Convener.

SECTION IX. (ELECTRICAL).—W. A. Chamen, M. B. Field, W. W. Lackie, Prof. Magnus Maclean, W. B. Sayers, E. George Tidd, and W. G. M'Millan, with H. A. Mavor as Convener.

Excursions and Entertainments.—Charles Connell, J. Duncan, A. Fullerton, H. E. Hollis, R. T. Moore, R. D. Munro, E. H. Parker, J. R. Richmond, A. D. Wedgwood, and J. Williamson, with James Rowan as Convener.

Rooms Committee.—Prof. Biles, G. T. Beilby, H. A. Mavor, J. D. Cormack, with Prof. Arch. Barr as Convener.

Billeting.—Councillor Burrell, John Cochrane, James S. Dixon, Robert Duncan, Alex. Fullarton, A. Bonar Law, M.P., Fredk. Lobnitz, Sam Mavor, George M'Farlane, J. F. Maclaren, Anderson Rodger, Jas. M. Thomson, and W. C. Warden, with Matthew Paul as Convener.

General Secretary.

Professor J. D. CORMACK,
University College, Gower Street, London, W.C.

Auditors.

John Mann & Son, Chartered Accountants, 142 St. Vincent Street, Glasgow.

Institutions and Sectional Office-Bearers.

SECTION I.

Railways.

Chairman: Sir Benjamin Baker, K.C.M.G., LL.D., F.R.S.

Vice-Chairmen: B. Hall Blyth.
Alexander Ross.
John Strain.

Honorary Secretary: R. Elliott Cooper, 8 The Sanctuary, Westminster, London, S.W.

SECTION II.

Waterways and Maritime Works.

Chairman: Sir John Wolfe Barry, K.C.B., LL.D., F.R.S.

Vice-Chairmen: William H. Hunter.
William Matthews.

Honorary Secretary: Professor L. F. Vernon-Harcourt, M.A., 6 Queen Anne's Gate, Westminster, London.

SECTION III.

Mechanical.

The Institution of Mechanical Engineers.

Chairman: William H. Maw.

Vice-Chairmen: Bryan Donkin
J. Hartley Wicksteed.

Honorary Secretary: Edgar Worthington, B.Sc., Institution of Mechanical Engineers, Storey's Gate, St. James's Park, Westminster, London, S.W.

SECTION IV.

Naval Architecture and Marine Engineering.

The Institution of Naval Architects.

Chairman: The Right Hon. the Earl of Glasgow, G.C.M.G.

Vice-Chairmen: Archibald Denny.
Francis Elgar, LL.D., F.R.S.
John Inglis, LL.D.

Honorary Secretary: R. W. Dana, M.A., the Institution of Naval Architects, 5 Adelphi Terrace, London, W.C.

SECTION V.

Iron and Steel.

The Iron and Steel Institute.

Chairman: William Whitwell.

Vice-Chairman: Sir Wm. Roberts-Austen, K.C.B., F.R.S.

Honorary Secretary: Bennett H. Brough, The Iron and Steel Institute, 28 Victoria Street, Westminster, London, S.W.

SECTION VI.

Mining.

The Institution of Mining Engineers.

Chairman: James S. Dixon.

Vice-Chairmen: James T. Forgie.
George A. Mitchell.

Honorary Secretary: James Barrowman, Staneacre, Hamilton, Scotland.

SECTION VII.

Municipal.

The Incorporated Association of Municipal and County Engineers.

Chairman: E. George Mawbey.

Vice-Chairmen: W. Weaver.
T. H. Yabbicom.

Honorary Secretary: Thomas Cole, 11 Victoria Street, Westminster, London, S.W.

SECTION VIII.

Gas.

The Institution of Gas Engineers.

Chairman: George Livesey.

Vice-Chairmen: Wm. Foulis.
W. R. Herring.
T. O. Paterson.

Honorary Secretary: J. W. Helps, Waddon, Croydon, Surrey.

SECTION IX.

Electrical.

The Institution of Electrical Engineers.

Chairman: W. E. Langdon.

Vice-Chairmen: R. K. Gray.
Professor Magnus Maclean, D.Sc.

Honorary Secretary: W. G. Macmillan, 28 Victoria Street, Westminster, London, S.W.

MINUTES OF PROCEEDINGS.

MONDAY, 2nd SEPTEMBER.

BANQUET.

In the evening at 8 p.m. a banquet was held in the St. Andrew's Halls, at which the Foreign Delegates and Honorary Members and the Members of the London Committee and the Executive Committee were present.

Robert Caird, LL.D., in the Chair.

The following was the toast list:—

" His Majesty the King," and " Queen Alexandra, the Duke and Duchess of Cornwall and York, and the other Members of the Royal Family," proposed by the Chairman.

" Foreign Governments," proposed by the Earl of Glasgow, and replied to by M. Berrièr-Fontaine (France); M. J. Troost (Belgium); and Comm. George Breen (Italy).

" Engineering Societies," proposed by Lord Provost Chisholm, and replied to by Herr O. von Miller (Germany); Herr J. H. Beucker-Andreae (Holland); Colonel Huber (Switzerland); Professor Carhart (United States of America); and Herr S. Eyde (Norway).

" The International Engineering Congress," proposed by Professor V. E. de Timonoff (Russia), and replied to by Mr. J. Mansergh and Mr. W. Foulis.

TUESDAY, 3rd SEPTEMBER.

GENERAL MEETING in the Bute Hall at 10 a.m.

In the Bute Hall of the University the Foreign Delegates and Honorary Members were received by the President, Mr. James Mansergh, F.R.S., and by the Honorary President, Lord Kelvin; the Hon. the Lord Provost of Glasgow, Samuel Chisholm, L.L.D.; Mr. Robert Caird, LL.D., Chairman of the Executive Committee; and the Very Reverend R. Herbert Story, Principal of the University.

Thereafter the President delivered to a large audience of the Members his Presidential Address.

ADDRESS OF THE PRESIDENT,

JAMES MANSERGH, F.R.S.

PRESIDENT OF THE INSTITUTION OF CIVIL ENGINEERS.

STANDING here, in virtue of my position as President of the Institution of Civil Engineers, to open the first General International Engineering Congress held in Great Britain, I am conscious of owing my elevation to this eminence to the accident of office, and not to personal desert. I feel keenly myself—and I am sure the feeling must be shared by many present—that it is an act of the greatest presumption on my part to occupy this position in the presence of the "Grand Old Man" of Glasgow's ancient University. I desire therefore to explain that the position has been forced upon me, notwithstanding my earnest remonstrance, and by the desire of Lord Kelvin himself. My words will therefore be few, and will be restricted to tendering a very cordial welcome to all engineers present—especially to those hailing from foreign and distant lands; to thanking the authors of the papers contributed to the various sections; and to making the briefest reference to certain matters of interest to us, as engineers working under modern conditions.

It has long been impossible for any individual to give adequate expression to the fulness of the combination of contemporary science, art, knowledge, and practice, which we recognise for engineering. Engineers constitute more than a profession; they amount to a "race"; and it is upon them, more than upon any other class of the civil population of the world, that falls the heaviest share of the "White Man's Burden." There have been framed many definitions of engineering and of the engineer; but none that I can esteem adequate, and at the same time sufficiently exact and exclusive. My reason for holding this opinion is based upon two considerations. The first is the persistence of much popular ignorance of the nature of our work, and some lack of appreciation of our class; and the second is the stubborn refusal of the English spirit to admit the necessity of any formal qualification on the part of those who claim to be of the profession. With us—odd as such a state of things must seem to our more highly organised foreign colleagues—an engineer may hold a diploma, but he need *not*. He may be associated with our Institution, and be entitled to append a string of capital letters to his name, or he may not possess a single title to nominal distinction. This is because with us engineering does not consist in *being*, but in *doing*. The public's unformed vague idea of an engineer is that of a man who can *do* things—a great and constantly increasing *number* of things—all falling within a wide but fairly recognised category. His quality seems to lean more to the side of invention than to that of scholarship. For my part I am content to have it *so*. Not that an engineer can ever be too deeply instructed, or too well trained in all the elements of knowledge and skill required for the effective pursuit of his calling; but the really great engineer is *born*, not *made*. So subtle is the influence of words upon thought, that I could wish the name of our avocation were spelt in English, as it is in languages of more pronounced Latin derivation, with a capital "I," instead of "E"—"Ingeniering", say, in place of "Engineering." Thus the nature of our work would be better recognised among the people, who are careless of etymologies. The suggestion of the name would be removed from association with the word "engine" (a word good enough in its degree, and one that once had a wider significance than is now left to it) and would be placed where it rightly belongs, with the root idea which gives us the words "ingenious," "ingenuity," etc. We must go no further however in this direction for the missing definition of engineering, or we shall get into the clouds, where, although I am not sure but that we might find some Colleges of Engineering, we should miss the substance of the thing itself.

For engineering is the only high art which for its excellence depends as much on its cheapness as upon any other item in the sum of achievement. All other things being equal—adaptability, soundness, efficiency—the engineering work which costs the least money is the best. I do not know any other product of man's creative and adaptive powers, of which the same can be so truly said. The "cash" basis is the real foundation upon which the engineer builds; and this consideration at once draws us away from judging of engineering as merely something cleverly done by an ingenious person. It also serves often to distinguish between college, text-book, or rule-of-thumb engineering, and the *real thing*. There is an American definition of an engineer, which states that "he is a man who can do *well* for *one* dollar things that anybody could do *somehow* for double the money." This is getting very near the truth. It is not the whole truth, of course; but that, for reasons I have already indicated, is unattainable. At any rate, it places in due prominence a quality which those who regard engineering studies from the college standpoint are apt to ignore. I have heard a legend of a professor of applied mechanics, who was shocked at the thought of steam engines being made for money, to sell—like *cakes*. A good deal of wasted ingenuity would be saved, if those who engage in every kind of engineering work would remember to use the money standard, as well as the foot-rule and the higher mathematics.

Actual engineering must be mastered as it is realised on works in progress. It has no authoritative text-books. The working engineer's library is sometimes largely composed of ephemeral manufacturer's catalogues, and lists of prices current of materials. Like the perfect artist described by Longfellow, the engineer must learn to work with the means that lie readiest to his hand. He must cherish his ideals, or he will sink into routine; but he, *of all men*, cannot afford to indulge in hobby-riding. He leaves as little as possible to chance, and, if he is wise, he will not rely upon his best mathematics any further than he can see them. If he starts with aptitude, plods on with patience, observes with insight, records with careful exactitude, and adapts with wisdom, in the fulness of time he will find himself, almost to his surprise, in possession of *judgment*; and this is the glory of an engineer, fitting him for his highest employment as man-of-all-work to civilisation. Material civilisation owes much to this faithful servant. Others may plot, scheme, invent, discover wants and their proper supplies; the engineer, as a rule, does chiefly what he is told *wants doing*. By strict attention to his own business, he helps to make the crooked ways straight and the rough places plain for *all*.

The engineer must have great power of concentration. His solicitude is to make every job a little better than the last. The newest steam engine shows a fractional economy of steam; the latest steamship carries her freight with a scarcely distinguishable saving in coal consumption *per ton*; the selected railway metal lasts a little longer than the previous purchase; the main line is straightened here and there; and—incidentally as it were—the remote ends of the earth are brought closer together, and plague, pestilence, and famine are driven back. The wiseacres who declare on political platforms that the effect of modern civilisation is to make the rich richer, and the poor poorer, forget all about engineering. The engineer is the chief of the modern democratic Civil Service. Civilisation is admitted to have had its birth with the Egyptians and its rearing with the Romans; and the latter were the first to recognise a change of purpose in engineering from the idle aims of Egyptian pyramid builders to the useful purposes of road-making and the provision of ample supplies of pure water for their cities. Down to the dawn of the century that has just closed, civil engineering did not surpass the works of the Romans, which indeed in some respects remained unequalled. With respect to the elemental need of the modern world for improved means of transportation, it may be said that the new civil engineering first broke out its own line in the notable discovery of the Scotsman, Macadam, that good roads could be made with stones broken small. The distinguishing note of modern engineering is that it subserves in the main the interests of the mass of the people. The greater comfort, better feeding, higher healthiness, freer movement of the people to outside congested urban areas to-day, as contrasted with the state of the populace of this and other countries a century ago, are chiefly attributable to the triumphs of our professional work.

An alarm has been sounded in our ears of late, warning us that we, the inhabitants of the United Kingdom of Great Britain and

Ireland, have touched our high-water mark in respect to the prosperity derivable from the prosecution of those manufacturing industries which are based upon engineering, or are by it served with the means of transport and communication. This may be so. Our nation has no royal secret for arresting the revolution of Fortune's wheel. When merchants first sought our shores to trade with the aborigines, their attraction was the native tin. The development of the country however was not arrested by the substitution of iron for bronze implements and weapons. Wool became in turn the staple product of the land, and carried its diversified fortunes bravely down almost to within living memory. We have long ceased to produce enough wool, or corn, or meat, for our teeming population. It is almost as much as we can do to find enough water to drink. The wisest man that graced the Court of the British Solomon who first united the kingdoms of Scotland and England would be sorely puzzled—if he were to revisit this realm—to understand how we all contrive to live.

The industrial development of the world has proceeded along the lines which one of the profoundest minds of the nineteenth century—Charles Darwin—traced for the life history of the planet. The course of economic progress is from the simple to the complex, from sameness to infinite diversity. In the history of Britain, the mining of a semi-precious metal for exportation was succeeded by pastoral pursuits, and these again were followed by agriculture and manufacturing enterprises. Good government kept order in the land, and saved it from devastating invasions. Margins realised over the cost of living formed capital, which went into fresh enterprises at home, and eventually overflowed into adventures for the conquest of markets abroad. All the time engineering dogged the way, making roads and inland waterways and harbours, and supplying tools and mechanical motive powers. A vast multiplication and diversification of employments for money, ingenuity, and toil, have resulted from the free play of the national genius; and have been carried to such a height by the indomitable spirit of the race, that now the waxing and waning of particular trades and interests from accidental influences do not alter the balance of the great account which the nation has opened with Fate. An illustration in point is spread before our eyes. Mark the difference between the conditions governing the prosperity of, say, a mining camp, and those prevailing over a vast and varied emporium, a manufacturing centre, such as this noble city. Glasgow flourishes, not by reason of the vogue of any particular trade that finds specially favourable situation on the banks of the Clyde, but because it is a microcosm of the universal activities which yield wealth. Its engineers can point with pardonable pride to the material framework and setting of this community—the artificially improved river, the systems of railways and tramways, the magnificent water supply, which have given Glasgow elbow room for her expansion—as the gains of engineering; but it is the peculiar diversity of Glasgow's energies that have won for her the rating of "Second City of the Empire."

The question of moment to Britishers is: Shall we maintain our ground? to say nothing of increasing our lead? I cannot tell; but this I do believe, that the character of the future of the country and the fruitfulness of our common calling depend chiefly upon the preservation of that freedom for the play of all the talents, all the energies, all the force of human initiative for the subjugation of the powers of nature and their direction to the service of mankind, which has enabled us to do so much in this regard in the past. Favoured simply by secured peace at home, and by the confidence felt by the masters of accumulated capital, engineering has hitherto showered its first fruits over our land. To-day these advantages have become internationalised. Gold flows daily to and from the capital cities of the earth for the smallest balance of gain; or—as engineers would describe the movement of a mobile fluid—under the slightest head of a pressure that is ever shifting. Brains are no peculiar possession of our nationality. The cosmic forces are the same everywhere. Economic conditions tend to wear down to a uniform level. Science knows no frontiers. The engineer is the truest free trader. He goes whithersoever he is wanted and finds most to do. Will he in future flourish best in Britain or abroad?

We hear much talk nowadays about the British need of more technical education for workers, and of better instruction in the art of living for the people generally; and I am not disposed to disparage this desire for more light. *There cannot be too much of it.* Nevertheless I hold liberty to be more precious than learning. The fullest freedom for the exercise of the inborn spirit of initiative, enterprise, and adventure, is the next essential to the occurrence of this spirit in the *individual* members of a race, for enabling the *whole* to make headway in the universal struggle for life and for a leading position. I fear that only too good a case could be made out for the allegation that a mistaken statutory system has discouraged in this country—for the time being, at least—the naturalisation and development of electrical engineering on the largest scale. In other words, the Electric Lighting Acts had the broad result of chopping up the business of electricity supply in this favoured land into morsels reduced to the parochial needs of local authorities. There was no freedom in the business. Instead of the electrical and mechanical development of lighting and power being undertaken in this country upon a scale proportional to its early promise, the work had to be done by "sample"—every small specimen differing from the others. Long years passed before any English engineer was in a position to give out an electrical power contract amounting to £100,000. Meanwhile our friends in America and on the Continent of Europe were forging fast ahead. So we lost our chance, and shall probably have to take other people's electric plant for some time: instead of striking out our own leading line, as did our *less governed* forefathers years ago in railway work and shipbuilding.

I should like to remark here, in parenthesis, how much of the real essence of economical engineering is contained in the work of settling standard sections of important constructive materials. This matter has been taken in hand by a joint committee of the Institution of Civil Engineers, the Institution of Mechanical Engineers, the Institution of Naval Architects, and the Iron and Steel Institute. It is my privilege to be *ex officio* Chairman of this

Committee, and we have already taken the evidence of representative men among makers, merchants, and users of steel and iron bars of all shapes and scantlings, and have received many written communications, all of which go to prove the great desirability of doing thoroughly the work of standardizing that the Committee have taken up. Sir Benjamin Baker, with a specially selected Sub-Committee, has charge of bridge and general building construction; Sir J. Wolfe Barry, with similar assistance, of railways; Colonel Denny of shipbuilding; and Sir Douglas Fox of rolling stock. In the hands of these eminent engineers you may rest assured the work will be well carried out; but we desire earnestly the active and cordial assistance and co-operation of all our brethren interested in this important matter.

In all the various sections to which you will now go to perform the real work of the Congress, you will, I think, find something that will serve to *focus* your attention upon the great engineering problems of our time.

I have no wish to discriminate among the papers; but it is plain that in Section I. Professor Carus-Wilson has undertaken the treatment of a matter of extreme interest, in writing of the "Economy of Electricity as a Motive Power on Railways at present driven by Steam."

Some highly important papers are to be read in Section II.; and it is a matter of peculiar gratification that we have been able to enlist the help of so distinguished a band of engineers from the United States of America and from the European Continent, for giving true international importance to the deliberations of this Section.

I am pleased to find that one of the most interesting of all inventions since the age of "Watt" in the domain of prime movers —the steam turbine—is to be discussed in Section III.

It is impossible to overrate the value of the section of metallurgy; and the number of papers promised testifies to the technical interest of the questions which await answers in this sphere of engineering energy.

In Section VII. two of the most pressing problems of municipal engineering—the disposal of sewage, and the housing of the poor—will, I am sure, be adequately treated.

In Section VIII.—gas engineering—sufficient proof will be given of the influence exerted on this industry by that invaluable invention of incandescent lighting, to which the Exhibition—of which our hosts may justly be most proud—owes so much of its evening brilliancy.

The applications of electricity to various purposes will be described in Section IX.; among them the wonderful "three-phase" system of power transmission, which promises so much in this connection.

Time forbids my going further into the various matters that crowd our minds on such an occasion as the present. I can therefore only commend you heartily and sincerely to the despatch of the important business you have undertaken; and trust that the fruit of increased knowledge which may be gathered from interchange of ideas will amply repay your trouble in coming here at the invitation of our Glasgow friends and confreres.

M. Berrier-Fontaine, directeur du Genie Maritime, Paris.—My Lord Provost and Gentlemen—I have no doubt one and all of the foreign engineers who have come from so many distant countries to attend the Congress and to take part in this unprecedented general international engineering gathering, will join with me in according our best thanks to the President who has been so fitly selected to preside over our distinguished meeting to-day. I need not say, sir, that we fully appreciate the very kind reception we are experiencing at your hands. We are most sensible of it. Why? Well, sir, we expect to gain much additional technical knowledge during this week of our stay with you in Scotland, and we greatly appreciate the good will, and the better understanding, between different nations which meetings such as these are so apt to develop. It is, therefore, from the bottom of my heart that in the name of all the foreign gentlemen here present I tender to you our most sincere thanks for your kindness—to you Sir, and to your colleagues, the British Engineers.

The President,—I thank you, gentlemen, for your kind appreciation of my remarks. I thank you particularly on behalf of the leaders of this Congress, mostly our friends in Glasgow, and especially must I thank M. Berrier-Fontaine for his kindly words.

The General Meeting then concluded.

PROCEEDINGS OF SECTIONS.

At 11.30 a.m. the sections met in the Sectional Rooms as follows:

Section I.—(Railways)—Botany Lecture Theatre.

(For summary of proceedings and abstracts of papers, see pp. 28 to 34.)

Section II.—(Waterways and Maritime Works)—Botany Laboratory.

(For summary of proceedings and abstracts of papers, see pp. 56 to 64.)

Section III.—(Mechanical)—Debating Hall, Students' Union.

(For summary of proceedings and abstracts of papers, see pp. 98 to 108.)

Section IV.—(Naval Architecture)—Humanity Lecture Theatre.

(For summary of proceedings and abstracts of papers, see pp. 146 to 153.)

Section V.—(Iron and Steel)—Chemistry Lecture Theatre.

(For summary of proceedings and abstracts of papers, see pp. 169 to 194.)

Section VI.—(Mining)—Greek Lecture Theatre.

(For summary of proceedings and abstracts of papers, see pp. 212 to 228.)

Section VII.—(Municipal)—Engineering Lecture Theatre.

(For summary of proceedings and abstracts of papers, see pp. 251 to 258.)

Section VIII.—(Gas)—Natural History Lecture Theatre.

(For summary of proceedings and abstracts of papers, see pp. 275 to 291.)

Section IX.—(Electrical)—Natural Philosophy Lecture Theatre.

(For summary of proceedings and abstracts of papers, see pp. 310 to 316.)

The meetings concluded at 1 o'clock, and in the afternoon the members took part in the following visits to works:—

1. Messrs. Dubs & Co., Glasgow Locomotive Works, and Messrs. Alley & MacLellan, Sentinel Engine Works, Polmadie.

2. Prince's Dock, and the Weir on the Clyde.

3. Messrs. G. & J. Weir, Holm Foundry, Cathcart.

4. Messrs. The Fairfield Shipbuilding & Engineering Co., Ltd., Govan.

5. Messrs. W. Baird & Co., Gartsherrie Iron Works, Coatbridge.

6. Messrs. The Waverley Iron & Steel Co., Coatbridge.

7. Messrs. The Steel Company of Scotland, Hallside Steel Works, Newton.

8. Tidal Weir and Swanston Street Sewage Works.

9. Gas Works at Dawsholm, and new Gas Works at Provan.

10. Organised Visit to the Electrical Exhibits in the Exhibition.

11. Messrs. Robert Maclaren & Co., Eglinton Foundry, Canal Street.

OPENING OF THE JAMES WATT ENGINEERING LABORATORIES, GLASGOW UNIVERSITY.

At 3.30 p.m. a large number of members and citizens assembled in the main Laboratory, on the invitation of the Engineering Laboratory Committee, Sir William Arrol, Chairman of the Committee, presiding. The Chairman briefly introduced Professor Barr, who made a statement regarding the history of the undertaking, referring especially to the donation of £12,500 towards the buildings from the Bellahouston Trustees, and the numerous subscriptions in money and apparatus received towards the equipment. Sir James King acknowledged the reference to the Bellahouston Trustees. Lord Kelvin (Honorary President of the Congress), then declared the laboratories open, and referred to the growing need for laboratory instruction, and the desirability of a close connection being maintained between the University and the engineering profession. Mr. James Mansergh (President of the Congress), delivered a short address on the scientific training of engineers, touching upon the action that the Institution of Civil Engineers had taken in requiring scientific knowledge as a qualification for associate-membership. The Lord Provost of Glasgow (Samuel Chisholm, LL.D.), and Mr. William Maw (President of the Institution of Mechanical Engineers), also addressed the meeting. Principal Story expressed his gratification in accepting this addition to the equipment of the University, and conveyed the thanks of the meeting to Lord Kelvin for the part his lordship had taken in the proceedings.

RECEPTION.

In the evening at 8 p.m. a reception was held in the City Chambers. The members were received by the Lord Provost (Samuel Chisholm, LL.D.) and the Magistrates.

During the evening the company assembled in the Banqueting Hall, and the Lord Provost, in the name of the Corporation, welcomed alike those strangers from afar and near who were visiting Glasgow in connection with the Congress, and welcomed also the citizens of Glasgow who were present.

Lord Kelvin, as a burgess of the city, joined with the Lord Provost and Town Council in giving all a hearty welcome to the City Chambers; and as Honorary President of the Congress, he thanked the Lord Provost for his hearty welcome to the Congress members.

Sir John Wolfe Barry also acknowledged the welcome.

Dr. Caird, in name of the foreign delegates, the members of the Congress, and the Local Committee, moved a vote of thanks to the Lord Provost and Corporation for their hospitality. Principal Story seconded the motion.

The Lord Provost replied briefly.

WEDNESDAY, 4th SEPTEMBER.

The Sections met as follows:—

Section I.—(Railways)—Botany Lecture Theatre. 10-1.

(For summary of proceedings and abstracts of papers, see pp. 35 to 46.)

Section II.—(Waterways and Maritime Works)—Botany Laboratory. 10-1.

(For summary of proceedings and abstracts of papers, see pp. 65 to 76.)

Section III.—(Mechanical)—Debating Hall, Students' Union. 10-1.

(For summary of proceedings and abstracts of papers, see pp. 109 to 126.)

Section IV.—(Naval Architecture)—Humanity Lecture Theatre. 10.30-1.

(For summary of proceedings and abstracts of papers, see pp. 154 to 161.)

Section V.—(Iron and Steel)—Chemistry Lecture Theatre. 10-1.

(For summary of proceedings and abstracts of papers, see pp. 195 to 211.)

Section VI.—(Mining)—Greek Lecture Theatre. 10-1.

(For summary of proceedings and abstracts of papers, see pp. 229 to 250.)

Section VII.—(Municipal)—Engineering Lecture Theatre. 10-1.

(For summary of proceedings and abstracts of papers, see pp. 259 to 265.)

Section VIII.—(Gas)—Natural History Lecture Theatre. 10-1.

(For summary of proceedings and abstracts of papers, see pp. 292 to 299.)

Section IX.—(Electrical)—Natural Philosophy Lecture Theatre. 10-1.

(For summary of proceedings and abstracts of papers, see pp. 317 to 330.)

In the afternoon the members took part in the following visits to works and excursions :—

VISITS TO WORKS.

12. Messrs. Neilson, Reid & Co., Hydepark Locomotive Works, Springburn; Messrs. Sharp, Stewart & Co., Ltd., Atlas Loco. Works.
13. Messrs. The Singer Manufacturing Co., Kilbowie.
14. Messrs. Babcock & Wilcox, Ltd., Renfrew.
15. Messrs. John Brown & Co., Ltd., Clydebank.
16. A visit to Messrs. David Colville & Sons, Steel Works, Motherwell, had been arranged but was cancelled owing to the death of Mr. John Colville, M.P.
17. Messrs. The Steel Company of Scotland, Blochairn Works.
18. Messrs. Edward Chester & Co.'s Engineering Works, Renfrew.
19. Fire Station in Ingram Street, and Hydraulic Power Station.
20. Messrs. The Furnace Gases Co., Ltd., Works, Carnbroe.
21. Messrs. Kelvin & James White, Ltd.
    Glasgow Corporation Telephone Exchange.
22. Messrs. Mavor & Coulson, Ltd., Dynamo Factory, 47 King Street, Mile-End, and Messrs. Duncan, Stewart & Co., Ltd., Engineers, Bridgeton.

EXCURSIONS.

I.—Excursion to Aberfoyle and Loch Ard.

Train to Aberfoyle, drive round Loch Ard and back to Aberfoyle, and train from Aberfoyle to Glasgow (via Killearn).

II.—Excursion to Lanark and Falls of Clyde.

Train to Lanark, drive to Falls of Clyde, Cartland Crags, Crossford, Tillietudlem, and train from Tillietudlem to Glasgow.

THURSDAY, 5th SEPTEMBER.

The Sections met as follows:—

Section I.—(Railways)—Botany Lecture Theatre. 10-1.

(For summary of proceedings and abstracts of papers, see pp. 47 to 55.)

Section II.—(Waterways and Maritime Works)—Botany Laboratory. 10-1.

(For summary of proceedings and abstracts of papers, see pp. 77 to 97.)

Section III.—(Mechanical)—Debating Hall, Students' Union. 10-1.

(For summary of proceedings and abstracts of papers, see pp. 127 to 145.)

Section IV.—(Naval Architecture)—Humanity Lecture Theatre. 10.30-1.

(For summary of proceedings and abstracts of papers, see pp. 162 to 168.)

Section V.—(Iron and Steel)—Did not meet for the reading of papers.

Section VI.—(Mining)—Did not meet for the reading of papers.

Section VII.—(Municipal)—Engineering Lecture Theatre. 10-1.

(For summary of proceedings and abstracts of papers, see pp. 266 to 274.)

Section VIII.—(Gas)—Natural History Lecture Theatre. 10-1.

(For summary of proceedings and abstracts of papers, see pp. 300 to 309.)

Section IX.—(Electrical)—Natural Philosophy Lecture Theatre. 10-1.

(For summary of proceedings and abstracts of papers, see pp. 331 to 340.)

VISITS TO WORKS.

During the day a visit, No. 26, was made to Collieries in the Hamilton District:—the Priory Pits of Messrs. Wm. Baird and Co., Ltd.; the Whistleberry Colliery of Mr. Archibald Russell; and the Palace Colliery of the Bent Colliery Co., Ltd.

Visit No. 27 was also made to Broxburn Oil Works.

In the afternoon the members took part in the following visits to works and excursions:—

23. The Caledonian Railway Locomotive Works, St. Rollox, and the North British Railway Locomotive Works, Cowlairs.
24. Messrs. Glenfield & Kennedy, Kilmarnock.
25. Messrs. Wm. Denny & Bros., Dumbarton.
28. Pinkston Tramway Power Station and Port Dundas Electric Lighting Station.
29. Port Dundas Electric Lighting Station and Pinkston Tramway Power Station.
30. Organised Visit to the Gas Exhibits in the Exhibition.

EXCURSIONS.

III.—Excursion to Loch Lomond.

Train to Dumbarton and Ardlui by West Highland Railway, steamer to Balloch, and train from Balloch to Glasgow.

BALL.

In the evening at 9 p.m. a Ball was held in the St. Andrew's Halls.

FRIDAY, 6th SEPTEMBER.

The members took part in the following visits to works and excursions:—

Visits to works:

31. Leith Docks and Excursion to the Forth Bridge.

EXCURSIONS.

IV.—Excursion Through the Kyles of Bute.

Train from Gasgow to Fairlie; sail from Fairlie in turbine steamer "King Edward," through the Kyles of Bute, and back to Fairlie between the Cumbraes.

V.—Excursion to Edinburgh and Forth Bridge.

Train from Glasgow to Edinburgh, drive to Forth Bridge, through Lord Rosebery's grounds, sail from Forth Bridge for an hour on the Forth, and train from Dalmeny to Glasgow.

VI.—Excursion from Broomielaw to Arrochar.

Steamer "Duchess of Hamilton," from Broomielaw down River Clyde, past the Cumbraes, round south end of Bute, through Kyles of Bute to Arrochar, via Rothesay, Dunoon, and Loch Long; drive to Tarbet (Loch Lomond), steamer "Prince George" to Balloch, and train to Glasgow.

DURING THE CONGRESS WEEK THE FOLLOWING WORKS, SHIPBUILDING YARDS, ETC., WERE OPEN TO CONGRESS MEMBERS BETWEEN THE HOURS OF 10 A.M. AND 5 P.M., EXCEPT WHERE OTHERWISE NOTED, ON PRODUCTION OF THEIR MEMBERSHIP CARD.

Arrol, Sir Wm., & Co., Ltd., Dalmarnock Iron Works, 85 Preston Street, Bridgeton (10-4).
Barclay, Curle & Co., Ltd., Engineering Works, Finnieston; Boiler Works, Kelvinhaugh; and Shipyard, Whiteinch.
Barr & Stroud, Scientific Instrument Makers, 46 Ashton Lane (closed 12.30 to 1.30 daily).
Beardmore, Wm., & Co., Engine Works, Lancefield Street.
Blackie & Son, Printers and Publishers, 17 Stanhope Street (closed 2-3 daily).
British Hydraulic Foundry Co., South Street (3rd Sept. only).
Caird & Co., Ltd., Shipbuilders, Greenock.
Carron Co., Carron Iron Works, Stirlingshire (3rd or 4th Sept.).
City Improvement Schemes.
Clyde Shipbuilding & Engineering Co., Ltd., Port-Glasgow.
Collins, Wm., Sons & Co., Printers and Publishers, 139 Stirling Road.
Coltness Iron Co., Newmains.
Connell, Chas., & Co., Shipbuilders, Whiteinch.
Craig, A. F. & Co., Engineers, Paisley.
Dixon, William, Ltd., Govan Iron Works, Glasgow.
Dixon, William, Ltd., Calder Iron Works, Coatbridge.
Duncan, Robert, & Co., Shipbuilders, Port-Glasgow.
Dunlop, D. J., Shipbuilders, Port-Glasgow.
Dunlop, James, & Co., Clyde Iron Works, Tollcross.
Dunlop, James, & Co., Calderbank Steel Works.
Edinburgh & District Tramways Company, Ltd., Cable Power Station, Tollcross, Edinburgh.
Etna Iron and Steel Co., Motherwell.
Fullerton, Hodgert & Barclay, Ltd., Engineers, Vulcan Works, Paisley.
Glasgow Central Station Extension and Plans, Resident Engineer's Office, Central Station.
Glasgow District Subway Co. Power Station, 173 Scotland Street.
Glasgow & South-Western Railway Locomotive Works, Kilmarnock.
"Glasgow Herald" Printing Office, 65 Buchanan Street.
Glasgow Harbour Tunnel Co., Hoists, etc., Plantation Quay.
Glasgow Iron and Steel Co., Wishaw.
Glebe Sugar Refining Co., Greenock.
Hyde Park Foundry Co., 54 Finnieston Street.
King, David, & Sons, Manufacturers of Electrical Castings and Sanitary Appliances, Keppoch Iron Works, Possilpark.
Lang, John, & Sons, Machine-tool Makers, Johnstone.
Lindsay, Burnet & Co., Moore Park Boiler Works, Helen Street, Govan.
Lloyds Proving House, 82 St. James Street, Kinning Park.
Lobnitz & Co., Ltd., Engineers and Shipbuilders, Renfrew.

London & Glasgow Engineering & Shipbuilding Co., Ltd., Govan.
M'Dowall, John, & Son, Saw Mill Engineers, Walkinshaw Foundry, Johnstone.
M'Farlane, Strang & Co., Iron Pipe Founders, Lochburn Iron Works.
M'Onie, Harvey & Co., Engineers, 224 West Street, South Side.
M'Millan, Archd., & Son, Ltd., Shipbuilders, Dumbarton.
M'Neil, John & Co., Engineers, Helen Street, Govan.
Mackie & Thomson, Shipbuilders, Govan.
Martin, Hugh, & Sons, Coatbridge.
Martin & Miller, Tanners, 847 Duke Street.
Mechan & Sons, Engineers, Scotstoun.
Miller, A. & T., Globe Iron Works, Motherwell.
Milne, Jas., & Son, Engineers, Milton House Works, Edinburgh.
Mirrlees, Watson & Co., Scotland Street Iron Works (Afternoons only).
Muir & Houston, Ltd., Engineers, Kinning Park.
Napier & Miller, Ltd., Shipbuilders, Yoker.
Napier Bros., Windlass Engine Works, 100 Hyde Park Street,
Outfall Sewer and Pumping Station, Dumbarton Road Bridge, Partick.
Penman & Co., Boilermakers, Caledonian Iron Works, Strathclyde.
Ross & Duncan, Engineers, Govan.
Rowan, David & Co., Engineers, 231 Elliott Street.
Russell & Co., Shipbuilders, Port-Glasgow.
Scott & Co., Shipbuilders, Greenock.
Scottish Cold Storage Co., 219 George Street.
Scottish Co-operative Wholesale Society, Ltd., Works, Shieldhall, Govan.
Shanks & Co., Ltd., Manufacturers of Sanitary Appliances, Tubal Works, Barrhead.
Simons & Co., Shipbuilders, Renfrew.
Smith, A. & W., & Co., Eglinton Engine Works, 57 Cook Street.
Smith, Hugh & Co., Possil Engine Works, off Possil Road.
Spencer, John, Ltd., Phœnix Iron Works, Coatbridge.
Stephen, Alexander, & Co., Shipbuilders, Linthouse.
Steven & Struthers, Brassfounders and Engineers, Kelvinhaugh.
Stewart & Menzies, A. & J., Clydesdale Steel Works, Mossend.
Stewart, Duncan & Co., London Road Iron Works, Bridgeton.
Sterne, L., & Co., Engineers, Crown Iron Works, 156 North Woodside Road.
Summerlee and Mossend Iron and Steel Co., Coatbridge.
Summerlee and Mossend Iron and Steel Co., Mossend.
Tullis, John, & Son, St. Anne's Leather Belt Manufactory, Bridgeton.
Thornliebank Co., Ltd. (The Calico Printers' Association, Ltd.), Thornliebank (closed 2-3 daily).
Ure, John, & Son, Regent Flour Mills, Sandyford.
Wemyss Bay Railway Widening, D. A. Matheson, Engineer in Chief, Caledonian Railway, Buchanan Street Station.
Woodside Steel and Iron Co., Coatbridge.

PROCEEDINGS OF THE SECTIONS.

SUMMARY OF PROCEEDINGS

OF

Section I.—Railways.*

TUESDAY, 3rd SEPTEMBER, 1901.

Sir BENJAMIN BAKER, K.C.M.G., D.Sc., LL.D., F.R.S., in the Chair.

"UGANDA RAILWAY."

Paper by Sir GUILFORD MOLESWORTH, K.C.I.E.

Abstract.

THE Uganda Railway is instructive—

1st, In showing the inferences that may be deduced from the study of maps and books of travel.

2nd, As an example of an excellent reconnaissance based on astronomical and barometrical observations.

3rd, As an instance of the combination of difficulties different from those ordinarily encountered by the engineer.

In 1891 the author had to advise the I.B.E.A. Co. on the question of railway communication with Lake Victoia. He had never been in the country, which before 1888 was practically a *terra incognita*, the only European who had succeeded in penetrating the country being Mr. Joseph Thomson in his rapid and necessarily superficial expedition through Masailand. What was known of the rest of the region was the result of conjecture, or native reports, gathered by missionaries. Stanley visited Lake Victoria via Congo, and Fischer had in 1883 passed through German territory to the Dogilani Plain and Navasha. In 1888 Jackson and Gedges expedition passed via Machakos to Navasha, and thence via Stotik to Lake Victoria. From these sources Ravenstein's map was compiled; and from it, and from the records of Thomson's and

* The full proceedings of Section I. are published by Messrs. Wm. Clowes & Sons, Ltd., Duke Street, Stamford Street, London, S.E. Price 5s. 6d. post free.

Jackson's expeditions published by the Royal Geographical Society, the author gleaned the information on which his advice was based. A map thus compiled must necessarily be sketchy and in points inaccurate; but, notwithstanding these defects, it afforded valuable information. Some idea of its inaccuracy may be inferred by the results of recent surveys near the mouth of the Nyando.

Little information was given about the escarpments which bounded the great rift that traversed the country. There were no records of any European having visited either the Mau Plateau or the Valley of the Nyando.

After careful study of the sources of information, he submitted to the I.B.E.A. Company a sketch map, on which he had marked the line of reconnaisance which he recommended for first trial, giving also the reasons for his advice, which may be summarised as follows: —

1. A typical section in a straight line from coast to lake was assumed.

2. A great volcanic rift existed, at least 20 miles in breadth, with escarpments 1500 to 2000 feet high.

3. A chain of lakes indicated that the rift extends throughout British territory, and therefore cannot be avoided.

4. A longitudinal section of the rift and its escarpments was assumed.

5. Close to the coast the Rabbai Hills, 700 feet high, had to be rounded.

6. Voi was an obligatory point for purposes of water supply.

7. From Rabai Hills the land rises steadily to 5000 feet at the rift.

8. The Tsavo River should be crossed between its confluence with the Sabaki and the River Mbololo.

9. Mackakos must be avoided either by the Athi Valley or an alternative route..

10. The ramifications of the Athi River indicated the probability of a low point in the escarpment, and the best approach to the rift near Ngongo.

11. The descent of the eastern escarpment should run in the direction of the rising rift floor.

12. The line should pass along by Lakes Navasha and Elmenteita to the culminating point at Nakuro.

13. An easy line would be obtained in the rift floor at this part.

14. The best point for ascending Mau escarpment was at Lake Nakuro.

15. The ascent should run in the direction of the fall of the escarpment.

16. A railway by Jackson's route through Sotik was impracticable.

17. The only probability of a favourable line descending to Lake Victoria was by Mau Plateau and the Nyando Valley.

18. A line via Nzoia River would involve a considerable detour and broken ground.

19. Beyond Ngongo, excepting the portion in the rift floor, the line must be difficult and costly.

Macdonald's expedition in 1891-92 entirely confirmed these inferences, with one exception, the main point of difference being that the route via Nzoia was followed instead of the Nyando, which was considered impracticable. This change involved a detour of about 100 miles, but when the permanent survey was made in 1898 it was discovered that the Nyando Valley was quite practicable, and the railway is now being made through it.

Macdonald's reconnaisance was very ably made by compass, pedometer, and aneroid barometer. The cross sectional slopes of the country were taken by Abney's level. Corrections were made for the diurnal barometic wave, which is very important in the tropics. Plans and sections were plotted in camp each day, and linked in by triangulation where feasible; otherwise by astronomical observation. The position each day was checked either by latitude and longitude with chronometer, or by longitude from occultations. Notes were taken of the dimensions, slopes, flood-marks, soil in bed and banks, all waterways, and of the general physical and geological features of the country.

The difficulties encountered in the construction were very great. A port had to be established, with jetties, moorings, cranes, steam launch and lighters, and connected with the terminus by a short railway with a gradient of 1 in 50. Store sheds and workshops had to be built, labourers housed, nearly all the labour had to be imported from India, many subordinates obtained in India or locally were incapable or inebriates, those sent from England were satisfactory. The staff was new to the work, the language, and each other. No supplies were available in the country; even poles and thatch for coolie sheds had to be imported. Native raids necessitated military escort for the first survey parties. The construction involved an organisation equivalent to the maintenance of an army of 15,000 men in a practically waterless country devoid of resources, and of all means of animal or wheeled transport, with a base of operations to which everything had to be imported from a distant country. Large condensing plant was needed to supplement the water supply, and a corn mill to grind the imported food. The line had to be constructed telescopically, and it was impossible to maintain working parties far in advance of railhead. Separate water trains had to be run, and locomotives had to take a heavy water tank to supplement the tender. Heavy temporary works were necessary to expedite the progress of railhead; 34½ miles of temporary diversions were needed for the first 300 miles; amongst these being the Macupa Bridge and the Mazeras Viaduct, built in 91 and 25 working days respectively. The ruling gradients on these diversions was 1 in 30, with curves 400 feet radius; these limited the power of the engines. On one temporary diversion the descent to the rift was made by four rope inclines with a maximum gradient of 1 in 2, making a total descent of 15,000 feet with a length of 6000. The engineering strike in England delayed the supply of locomotives, rolling stock, and bridges. The first 250 miles were infested with tsetse fly, fatal to transport animals; nearly all of those imported died. Jiggers abounded, causing ulcers, which often necessitated amputation of one or more toes. Man-eating lions killed 28 of the Indian labourers, and caused a panic. Waves of fever passed over the country, and at one station 90 per cent. of a working party were down with it. It was necessary to organise an agency in India for labour and materials, a postal service with regular mails, a force of 200 police, complete hospital staff, a temporary telegraph beyond railhead; and a small steamer had to be carried piecemeal by porters to the lake. The viaducts over the deep ravines in the descent into the rift had to be constructed telescopically. The responsibility for the whole of this organisation rested on the chief engineer, and very great credit is due to him and his staff for the able manner in which these difficulties have been met.

Mr. A. E. Welby and Mr. Wigham Richardson took part in the Discussion.

The author replied, and on the motion of the Chairman a vote of thanks was accorded to him.

Mr. A. E. Welby, at the Chairman's request, contributed some additional notes on the paper.

Mr. ALEXANDER ROSS, Vice-Chairman, in the Chair.

THE ECONOMY OF ELECTRICITY AS A MOTIVE POWER ON RAILWAYS AT PRESENT DRIVEN BY STEAM.

Paper by Professor C. A. CARUS-WILSON, M.A.

Abstract.

THE paper deals with the economic considerations which will probably govern the substitution of electricity for steam as a motive power on railways.

Branch or cross country lines are the least profitable part of present railway systems, and in many cases the receipts barely cover expenses. The competition of electric tram lines now being built throughout the country will still further accentuate the unremunerative character of branch lines. With steam traction it is necessary to make up long trains, so that on branch lines with little traffic the interval between trains is large and entails delay in making connections with main line stations. This infrequency of service causes unpunctuality, as the limited traffic does not warrant the employment of a staff adequate to cope rapidly with long trains heavily laden with passengers and luggage, which come in at infrequent intervals. This need not necessarily be the case if the traffic were evenly distributed over the working day, as the existing staff would be able to cope with a considerable increase of passenger traffic. By breaking up the train service on branch lines into smaller units moving more frequently, cross-country travel would be greatly facilitated.

It is thereore necessary to ascertain upon what the cost of any increase of train service depends, so as to deduce the minimum traffic required to pay for it. To do this with steam railways, the running expenses, such as coal, drivers' and conductors' wages, etc., per train-mile, which vary with the number of trains run, must be separated from the fixed expenses, such as maintenance of way, traffic expenses, etc., which do not so vary.

The fixed expenses per train-mile, multiplied by the number of trains per day on any given line, will then give the contribution of that line per day-mile to the general fund for maintenance. This constitutes a fixed sum per day-mile which must be provided for

under the new conditions, together with the increased running expenses. The traffic per day-mile must exceed this amount, plus a sum required to pay interest on the electric installation, before the line can be said to pay.

An analysis of the Board of Trade returns* of the working expenses of the principal English railways for 1900 shows that the fixed expenses increase when the proportion of passenger traffic to goods traffic is increased. Thus, on the Midland Railway, where the passenger train-mileage is 40 per cent. of the whole, the fixed expenses are only 22.6 pence per train mile; whereas with the Great Western and Great Northern Railways, where the goods and passenger train-miles are equal, the fixed expenses vary from 23d. to 25d.

On the other hand the item of running expenses remains fairly constant for all the principal lines, despite the difference in the proportion of passenger and goods traffic. Thus, the Midland Railway, with 60 per cent. of goods train-miles and 1.43 tons per train-mile, has the same running expenses as the Lancashire and Yorkshire Railway with 35 per cent. of goods train-miles and 3.33 tons per mile. An exception occurs in the case of the London and Brighton and South Eastern Railways owing to the high price they had to pay for coal last year. The analysis demonstrates that the running expenses do not rise above the average unless there is a very large proportion of heavy goods traffic.

In comparing steam with electric traction, we may assume the case of a branch line with six steam trains each way per day. Taking the fixed and running expenses of a normal line like the Great Northern for the purpose of illustration, the running expenses will be 12×11.85d. $= 142$d., and the fixed expenses will be 12×21.38d. $= 256$d., per day-mile. If the line is to contribute to the general revenues a sum proportional to the trains run and to the average cost per train mile for the whole of the line, the receipts per day-mile must equal 398d.

Instead of the steam train running every two hours we may substitute an electric train, composed of motor-driven cars with ordinary carriages trailing, running every half-hour, but with a quarter of the seating accommodation. About 20 per cent. dead weight is saved by dispensing with the locomotive; and, as the weight of the carriages is only a quarter, the new trains will weigh one-fifth of the old ones. This reduces the coal item in the running expenses to 0.68d.,† and water, oil, etc., to 0.15d., as against 3.36d.† and 0.77d. respectively for steam trains. The experience of the City and South London Railway shows that the cost of wages and

* This Table is given in the Paper.

†The price of coal is taken at 8s. per ton.

materials for repairs is halved, bringing these items down to 0.67d. and 0.52d. for electric railways. The simplicity of the electric equipment makes it possible to substitute one motor-man for the highly-paid driver and fireman; so that the item of wages on the locomotive is also halved. The electric motor car is ready to start at any time, and a larger proportion of actual working hours can be usefully employed; so that the men can put in about 50 per cent. more train-miles, thus reducing the wages item to 2.25d. To this must be added the wages of the men at the generating station, estimated at 0.62d., or half the motor-man's wages, thus making the wages per train-mile altogether 2.87d. The total cost per train-mile for running expenses for electric traction is therefore 4.89d., as against 11.85d. for steam traction.

With electric traction the fixed expenses would be the same as with steam traction, but the running expenses would increase with the frequency of the service. In the case assumed, with trains every half-hour, or twenty-four each way per day, the running expenses would be $48 \times 4.89\text{d.} = 240\text{d.}$, and the fixed expenses being as before, 256d., the total expenses per day-mile would come out at 496d. In order to pay expenses the receipts would have to increase from 398d. to 496d. per day-mile, or about 25 per cent. This, however, would not pay the interest on the capital required for the electrical equipment. The generating station, rolling stock, and distributing system for a half-hour's service of 40-ton trains on a line 15 miles in length, would probably be about £8000 per mile, which at $3\frac{1}{2}$ per cent. interest would require additional receipts of 184d. per day-mile. The total increase of traffic required to pay all expenses and interest would therefore be about 70 per cent. Assuming that a fourfold increase in the number of trains per day were to double the traffic, the profits per day-mile would be 10s.; if the traffic were trebled the profits would be 43s.

The profits per day mile on the whole of the Great Northern system average 124s.; so that the adoption of electricity on branch lines is worth considering as a means of making them contribute a more substantial proportion of the total profits than they do at present.

Mr. Hurry Riches and Sir Douglas Fox took part in the Discussion. The author replied, and has also replied by correspondence.

On the motion of the Chairman a vote of thanks was accorded to the author.

The meeting was then adjourned.

WEDNESDAY, 4th SEPTEMBER, 1901.

Mr. ALEXANDER ROSS, Vice-Chairman, in the Chair.

"MODERN PRACTICE IN RAILWAY SIGNALLING."

Paper by I. A. TIMMIS.

Abstract.

THE changes which steam effected when it came into use as an aid to more rapid movement of people and material on land and water, created an ever-increasing desire and want for more perfect and faster means for effecting that movement. And, now that another force of nature—electricity—has come to the aid of steam, the growth of railways has developed enormously, and the desire and necessity for intercommunication in all countries has not only increased, but must go on increasing; as a consequence, the engineers of railways are obliged to fit new signalling systems in order to deal with the larger stations, greater number of main lines and sidings, larger cabins, the increase in number of trains and higher speeds. It has become necessary to place the points and danger signals at a greater distance from the cabins. The result of these altered conditions is that some other power is required to take the place of manual. Three systems have been tried—hydraulic, pneumatic, and electric.

HYDRAULIC.—The experience gained from signal work operated by this system proves that it cannot compete with the pneumatic and electric systems, and so the author did not deem it advisable to take up time in describing it.

PNEUMATIC.—There are two systems that use air:—

1. *The Westinghouse High Pressure.* In the first installations that were fitted in the United States the signals and points were operated by the air conveyed through a main supply pipe and its branches to a cylinder on each signal post and at each pair of points, and the air was admitted to the cylinders by hydraulic power, which was put into action at the signal cabin by the signal man moving a small lever. The hydraulic pressure acted on a valve, which admitted the air into the cylinder, and moved a piston. But a later development introduced an electric current as the controlling agent. The levers in the cabin are interlocked; when a signal lever is pulled over, an electric current is sent to an electro

magnet on the signal post, which compresses a spring, closes the exhaust port, and opens the high pressure air admission valve. The piston in the cylinder then lowers the signal. When the electric current is interrupted the spring closes the valve, opens the exhaust, pushes back the armature, and the counter weight puts the signal to "danger." When a point lever is moved in either direction the operation of the points, in each direction, is practically as described for the signals. Thus there is a magnet controlling each end of the point cylinder with one slide valve. But there is a third magnet to lock the slide valve, and in addition it breaks and changes the electric circuit and sends an indication current back to the signal cabin when the points are over and locked, and this current operates an electro magnet in the cabin, which enables the signalman to lower the necessary signals.

2. *The Low Pressure Pneumatic.* This system is altogether on different lines from the high pressure. The operating is effected by air at 15lbs. pressure, and the controlling by air at half that pressure.

To operate points the lever is pulled over half way, and is then stopped. The controlling current goes to the points and admits the higher pressure air into a cylinder, when the points are moved and locked, and a return indication is sent to the cabin, which releases the lever and completes its throw. The movement of the points and the locking bar and locking bolt are effected by a plate or flat bar with grooves and studs in it. There are four pipes to work each signal—main supply, two controllers, and one return—and there are five pipes to a pair of points.

Both the above systems can be fitted to work with a track circuit, but this involves the use of electricity, and adds considerably to complication of detail.

Electric.—In the United States a system is fitted by the Union Switch and Signal Co., where the power is supplied from primary batteries, and each signal is lowered to "line clear" by a small motor geared 1000 to 1. An electro magnet then holds the signal, and the motor is cut out. When the circuit is broken the signal goes to "danger" automatically.

Another system, fitted by the Taylor Co., uses secondary batteries, and the signals are operated practically in the same way as just described. Points are also worked by motors geared 20 to 1 to the driving wheel. The first quarter revolution of the wheel unlocks the points, and the last quarter locks them and closes the return indication circuit to the cabin, and reverses the connections for a reverse movement. Interlocking is effected in the cabins in the lever frame.

In this country the first practical system fitted was on the Liverpool Overhead Railway. This is an automatic system, and of course only works the signals. A full description is in "Engineering" of February 10th, 1893. As a train leaves a station it puts the starting signal to danger by means of a striking bar fitted to the rear vehicle operating a breaking contact; and when the train is a suitable distance ahead of the signal the same bar operates a making contact which closes a cuircuit. This circuit is completed by the signal just passed being at "danger," and then the signals in the rear block are lowered automatically to "line clear." The train goes on to the "home signal" at the next station, and puts it to "danger." There is thus always at least one signal at "danger" in the rear of a train, and no vehicle can be left on the line if the signals are lowered in a block. An electro magnet of the "long pull" type operates each signal with some 250 watts, and the current strength is automatically reduced to one-tenth as the signal is lowered. The points are electrically interlocked with the signals on both lines at the cross-over roads, and in addition they are mechanically locked. After the author had fitted the signal work on the Liverpool Overhead Railway, he fitted a small but complete installation, not automatic, on the Western Railway of France, by which the signals and points are all worked by electro magnets, and the points are all locked and repeating. The Western Railway of France have adopted that system. Since then he fitted another automatic system on the small circular railway, two miles in length, in the Paris Exhibition of 1900, practically on the same lines as that on the Liverpool Overhead Railway, but the signal arms and magnets, and resistance and contacts, are all small and light, and encased so as to avoid the action of wind and weather.

The paper discusses the important non-automatic installation—the "Crewe system"—at Crewe, where some 1200 levers are being fitted, and nearly one-half are finished or well in hand. The signals are fitted in principle similarly to those on the Liverpool Overhead Railway, except that a counter weight has been attached. Each pair of trailing points is operated by a pair of magnets, but the facing points are operated and locked by an electric motor designed and made at Crewe, which, by the aid of worm gearing, completes the work. The first part of the travel of the gearing unlocks by half the throw of one rod; then the other rod moves the points over by a complete throw; and then the other rod, by the completion of its throw, locks the points again, and sends a return indication current to the cabin, which enables the signalman to complete the movement of his lever, and at the same time the selector rod at the points determines what signals can be lowered. Unless the points are locked, no signals can be lowered.

The 300 lever cabin now being fitted will have only about 150 cables of ⅝-inch diameter, from the cabin, each cable holding several leads. But if the low pressure pneumatic system were to be fitted to do the same work, it would require 1200 tubes from the cabin. This is a condition which is of very serious moment, and is an important factor in favour of electricity.

The final system to be considered is also entirely electrical, and embraces a track circuit. It is necessary to describe it, because there can be no question that in the near future all lines of railway heavily charged with passengers and goods, mixed traffic, including fast expresses, must have a track circuit fitted; and there is also no doubt that the initial difficulties which were met with in the earlier attempts have been sufficiently overcome to render it a certainty.

In this system, as in other systems, the levers in the cabin are, of course, mechanically interlocked. The signals are worked with the same magnets and gearing, only more powerful than on the Liverpool Overhead Railway. The points are operated and locked by a pair of electro magnets with a 7-inch throw, and the final travel of the magnets is softened in its force by an air cushion. At the same time a return current is sent to the cabin lever, which completes the throw of the lever and advises that the points are locked. When the signal is lowered the circuit is completed in the lever frame, and the lever is held in the forward position by a small electro magnet, and when the current is broken the lever goes automatically to the back position. Thus the signalman knows what is done. This arrangement enables a track circuit to be fitted economically. This circuit has a small battery in each block operating a small magnet, which, when energised, completes the main circuit.

It should be stated here that, if electric leads for such low potentials as not over 200 volts are properly fitted, it is absolutely impossible for any circuit to go wrong. There is no force of nature so constant, so easilv taken from place to place, or so instant in its action as electricity.

The Chairman, Sir Douglas Fox, Mr. F. W. Webb, and Mr. W. B. Worthington took part in the Discussion. The author replied to their remarks, and also replied to the Discussion by correspondence.

On the motion of the Chairman a vote of thanks was accorded to the author.

Sir Benjamin Baker, K.C.M.G., D.Sc., LL.D., F.R.S., in the Chair.

SUDAN GOVERNMENT MILITARY RAILWAYS.

Paper by Major C. B. Macauley, R.E.

Abstract.

The Sudan Government Military Railways consist of two branches, which start from Wadi Halfa and pass through different kinds of country. One branch goes in a south-easterly direction to Khartoum, 576 miles by rail; and the other branch goes in a southerly direction to Kerma, in the Dongola province, a distance of 203 miles by rail.

The railway was laid primarily to supply an army in the field; and, partly as a consequence of this, nearly 50 per cent. of it is laid in desert. This necessitates that every train leaving one terminus for another shall take five special tank trucks to carry the 9500 gallons of water which are necessary for crossing the waterless desert.

The Khartoum Branch.

This leaves Wadi Halfa and goes through the Nubian Desert—a flat, waterless, sandy desert with hardly any vegetation—to Abu Hamed (230 miles). This section, on which there are nine stations for crossing trains, is so flat that it contains a piece of line 45 miles long without a curve, cutting, or embankment. Water was found at two places, by sinking wells, at depths of 72 feet and 96 feet. At a point 126 miles from Wadi Halfa there are small shops and an engine pit, and at Abu Hamed (230 miles) there is a running shed and workshop. From this last station to Shereikh (292 miles) the line follows the river, the country being less flat, and then makes a detour into the desert to avoid rocky country. At Abadia (340 miles), where there are shops and engine pits, the line again approaches the river.

From Abadia to Berber (362 miles)—the most important place on the line between the termini—and from Berber to the Atbara River (385 miles) the line runs across flat plain covered with scrub. It crosses the river by a seven-span bridge, 1050 feet long, consisting of girders resting on pairs of cylinders sunk into the river bed upon rock foundations. From this point the line approximately follows the Nile through flat plain and scrub, avoiding rocky country, which begins about 3 or 4 miles away from the river. This section, intersected by numerous watercourses, is liable to being flooded in the rainy season; and it is often washed away in places owing to the few bridges and culverts which exist at present. It was impossible to build these at the time owing to the rate (2000 to 2800 yards per day, with a maximum of 5100 yards in one day) at which the line was built. This is now being remedied as quickly as possible. Owing to the presence of the white ant, steel sleepers are necessary on this part of the line.

Between the Atbara and Wad Ben Naga (496 miles) there are five stations, the one at Shendi (471 miles) being of importance, as it contains workshops, engine pit, coal and general stores. There are many villages along the river banks, and a considerable amount of cultivation in the country traversed by this section of the line.

From Wad Ben Naga to Wad Ramleh (545 miles) the line again traverses desert, and from Wad Ramleh it runs parallel with the Nile, across a flat plain containing several large villages, till it reaches Halfaya station, the terminus (576 miles), which is situated opposite Khartoum on the Blue Nile.

The steepest gradient on this branch is 1 in 120. The heaviest pull on the line is from Wadi Halfa to No. 5 station (103 miles), a difference in level of 1564 feet, and practically up-hill all the way. And from the latter station to Abu Hamed (230 miles) the line falls 810 feet, after which there are no very long gradients. The usual curves on this branch are 2865 feet radius, the sharpest being 955 feet.

The Kerma Branch.

The line follows the river as far as Sarras (33 miles). For the first five miles it crosses a flat, sandy plain to the second cataract, and from there it passes through rocky country. The cuttings (some 40 feet deep through rock) and embankments on this section are the largest on the lines. The gradients are numerous and as steep as 1 in 60; and the curves are numerous and as sharp as 500 feet radius. There are 24 bridges on this section, mostly iron-plate girders with stone abutments. The largest is 100 feet long, in three spans. This section, built years ago, could not have been constructed in the hurry of an expedition, as the work is generally far heavier than on any other part of the lines.

At Sarras the line winds in and out of rocky hills, chiefly following dry watercourses to Akasheh (86 miles). Between these two points there are two stations for crossing trains, the latter—at Ambigole wells (64 miles)—containing a good and constant water supply. From Akasheh to Ferket (99 miles) the country is so rocky that, to avoid cuttings, the railway winds in and out in a most extraordinary manner. This part of the line is liable to being washed away; but owing to the great expense of laying a safer line it was considered better to take the present risk.

From Ferket to Kosheh (105 miles) the line runs along the river, the banks of which are well cultivated. At Kosheh, which has a small running shed, the river makes a large bend, and the railway leaves it to go across a fairly flat desert to Dalgo (174 miles). There are two crossing stations and one 200-foot bridge on this section. From Dalgo the line follows the river for 10 miles and then crosses the river to Kerma (203 miles), the terminus, where there is a running shed and workshop. Kerma, the starting place for steamers to Dongola, is a large village with a considerable traffic in dates, grain, and ostrich feathers.

Details of the Khartoum and Kerma Branches.

The gauge of both branches is 3 feet 6 inches. Vignoles rails are used, varying from 36 to 50 lbs. The older sections, especially the Kerma branch, have the lighter rail. Creosoted and uncreosoted wood sleepers, and 81-lb. steel sleepers, are used. The rails are fastened to the wooden sleepers by spikes, without bearing plates, and to the steel sleepers by keys. On the Khartoum branch the line is only ballasted in a few places; but this will be remedied later. Very few bridges exist at present, but more are being built. The type adopted, with the exception of the Atbara bridge, consists of steel plate girders in 50 and 30-foot lengths, with rails laid on the top booms. The culverts consist of 2-foot cast-iron pipes set in masonry, with an apron on the down-stream side to prevent scouring away the foot of the bank.

The stations on both branches are rather primitive; but at Halfanya, Shendi, and Halfa there are proper stone buildings. On the Khartoum branch there are 19 crossing, 11 watering, and 15 coaling places for trains, and 6 places with triangles—no turntables being used. On the Kerma branch engines can water at 6 points, and there is a reserve of coal at every station. There are triangles at 3 points. The main workshops are at Wadi Halfa. These comprise a running shed holding 12 engines, an erecting shop, a smith's shop, a machine shop with lathes and other appliances driven by a 45 H.P. horizontal compound engine, a brass and iron foundry, a boiler yard, carpenter's shop with circular saws and other appliances, and also two carriage repairing shops.

Owing to the light rails and bridges on the older sections of the Kerma branch only one class of engine—a four-wheeled, coupled, 30-ton tank engine, drivers 3 feet 9 inches, outside cylinders 14 inches by 20 inches—is used. The engines on the Khartoum branch are heavier, some of them weighing 50 tons. There are seven types of engines in use due to the rapidity with which they had to be procured. Some are eight, some six, and some four-wheel coupled; the drivers vary from 3 feet 3 inches to 5 feet in diameter; all have outside cylinders, of various dimensions. The passenger stock is of the Indian type; but two trains-de-luxe, with sleeping and dining cars, and some spare cars are now being bought. The goods stock consists of high- and low-sided 10-ton trucks, of 14-ton and 12-ton covered trucks, and of brake vans, all with double bogies. There are also some four-wheeled, 5-ton trucks, brake vans, high-sided trucks, and cattle trucks.

The line is worked on the absolute block system, telephones being used. There are no safety appliances, such as facing-point locks, etc.; but the question of providing these is being considered. The ordinary train service to Khartoum consists of two fast trains weekly each way—connecting with the two principal mails from north and to north—and one slow train daily each way. The latter is a goods train and carries south Government supplies, stores, building materials. It brings back gum, ivory, senna, ostrich feathers, and grain, and also carries passengers. The service to Kerma consists of two mail trains each way weekly, connecting as above with the European mails, and about three or four other trains weekly each way. A good deal of grain is brought from Kerma for the army at Khartoum. Most of the stores are kept at Wadi Halfa, and owing to the cost of transport they are very dear. Coal, which costs about £3 per ton, is stacked in the open.

One of the greatest difficulties experienced on these lines is the abnormal wear and tear caused by sand. Unskilled labour is plentiful, but indifferent. Skilled labour is scarce; and, being imported at present, it is consequently dear. The natives, however, show a desire to learn trades, and fifty apprentices are now employed in the workshops at Wadi Halfa. The lines cannot be considered as finished, but it is estimated that they will be completed in the course of a year or so.*

The Chairman, Sir Guildford Molesworth, and Sir Douglas Fox took part in the Discussion; but there was no reply as the author was at Khartoum.

On the motion of the Chairman a vote of thanks was accorded to the author.

---

* The Report was written during midsummer, 1901.

Mr. B. HALL BLYTH, M.A., Vice-Chairman, in the Chair.

"AUSTRALIAN RAILWAYS."

Paper by PROFESSOR W. C. KERNOT.

Abstract.

AUSTRALIA is about 2500 miles long by 2000 broad. Its climate is temperate in the south and tropical in the north. It produces wool, wheat, horses, cattle, sheep, dairy produce, sugar, coal, gold, and other metals. Population, 3,800,000 at present, and is steadily increasing. Divided into five states, which, with the adjoining island of Tasmania, are united to form the Commonwealth of Australia.

A coast range runs round most of its perimeter. Outside this is a comparatively narrow strip of usually fertile country, with good rainfall and short, swift rivers, navigable only near their mouths. Inside is a vast shallow basin, with small rainfall, often arid surface, and long, tortuous rivers, precariously navigable, which in some cases ultimately reach the sea, but in many others lose themselves in swamps. This inland basin is useful for pastoral purposes in the eastern portions, but in the western is a nearly valueless desert, which, however, has important towns in it at places where gold abounds.

Railway making commenced at Sydney and Melbourne, the two largest cities (now possessing about 500,000 inhabitants each), soon after 1850. Melbourne, together with some other parts, acting under advice, adopted the 5 feet 3 in., or Irish, gauge. Sydney, after having agreed to 5 feet 3 inches, went back to 4 feet 8½ inches. Queensland somewhat later adopted 3 feet 6 inches; so did Tasmania and Western Australia. Thus a most unfortunate confusion of gauges has come into existence.

There are now 12,554 miles of State railways in Australia, of which 3725 are 5 feet 3 inches; 2811, 4 feet 8½ inches; 5970, 3 feet 6 inches; and 48 miles, 2 feet 6 inches, as well as about 1000 miles of private line, mostly 3 feet 6 inches.

GRADES.

In crossing the coast range and its spurs severe grades and high summit levels occur. The western line of New South Wales rises 3300 feet in 30 miles, requiring long continuous grades of 1 in 33, and in one case nearly two miles of 1 in 30. The northern line of

Victoria rises 1880 feet in 42 miles, having long grades of 1 in 50. The line from Adelaide to Brisbane, via Melbourne and Sydney, crosses the coast range six times, and reaches a summit level of 4473 feet. Of its total length of 1783 miles, 134 are above 3000, 409 above 2000, and nearly 800 above 1000 feet—grades ascending and descending 1000 feet in 10 to 12 miles, and having inclinations of 1 in 50, 1 in 40, and even in one instance 1 in 30 occur.

Grades have in some cases been recently improved, but this cannot be done where they are continuous for many miles, as is the case at some of the most difficult parts.

CURVES.

In Victoria 40 chain curves are usual on main lines, but in New South Wales and South Australia curves as sharp as 12 and even 10 chains occur at mountainous parts. On the 3 feet 6 inches gauge 5 chain curves are usual.

PERMANENT WAY.

The double-headed rail originally used has for many years been given up, and a steel rail of Vignoles pattern substituted. 100 lbs. per yard is standard for busy suburban; 80 for main lines; and 60 for branch lines are common on the wider gauges.

The lines are well made, with good storm ballast and heavy eucalyptus sleepers. Accidents from derailment are rare.

STRUCTURES.

In the eastern colonies large use is made of the local timber for bridges, culverts, and viaducts, but there are many fine iron and steel bridges over the larger rivers. The Hawkesbury Bridge in New South Wales, the Albert Bridge in Queensland, and the Mowabool and Melton Viaducts and Echuca Bridge in Victoria are noteworthy.

Tunnels are not numerous. New South Wales possesses the greatest number and length. Tunnels are always substantially lined, and give but little trouble.

Stations usually of English type. Permanent stations are not yet built in Melbourne or Sydney, but are about to be constructed. Signalling appliances of English type. Interlocking points and signals usual at important stations and junctions.

LOCOMOTIVES.

Owing to severity of grades and character of traffic, power is required rather than speed; hence small wheels and coupling are general. The Victoria standard engines are four or six coupled, with inside cylinders. Those of New South Wales, four, six, or eight, coupled with outside cylinders and leading bogie. Six coupled engines of 56 tons, not including the tender, and indicating over 1000 horse power, are used for express trains on the heavy grades. On the 3 feet 6 inches lines outside cylinder engines, with small wheels, from six to eight coupled, are general. American engines are used to some extent, especially on sharp curves; but English, or locally made engines of English type, are usually preferred as being more economical in point of fuel consumption and repairs. The Westinghouse brake is general. One private line in Tasmania uses the Abt rack on a 1 in 16 grade, the gauge being 3 feet 6 inches.

PASSENGER CARRIAGES.

Usually of European type, with steel under-frames and four or six wheeled bogies. The later ones on the broader gauges have a corridor at one side, lavatories and sanitary conveniences, and are lit with Pintsch gas. Sleeping cars of the Pullman type are used in New South Wales, and of the Mann type between Melbourne and Adelaide.

GOODS STOCK.

Usually of English type on four wheels, but occasionally double bogie vehicles are seen. Special wagons for carrying sheep, cattle, frozen meat, and dairy produce are used. The Westinghouse brake is usually fitted.

SUBURBAN RAILWAYS.

The largest suburban system is at Melbourne. The principal station has 500 trains in and the same number out each day. The accommodation is good, and the fares very low, 1s 4½d first-class return to a point 11 miles from town, and one shilling first-class return to one 9 miles out being representative fares. In one special case the charges for 9 miles are only 4½d first return and 3d second.

ADMINISTRATION.

Australian railways are usually made and worked by the State. The system is generally approved, in spite of certain dangers and mistakes in the past. Each system has a Commissioner, or Board of Commissioners at its head. The Commissioners are permanent officials of very high standing.

The average cost per mile of Australian railways up to date, and percentage of net revenue to capital, is as follows:—

	Cost per mile.	Percentage nett revenue.
Victoria	£12,300 ...	3.07
New South Wales... ...	13,700 ...	3.63
South Australia	7,500 ...	3.90
Queensland...	6,900 ...	2.67
West Australia	5,000 ...	5.81
Tasmania	8,200 ...	1.11

In conclusion, Australian railways, despite minor defects, are substantial, safe, and efficient, and of immense value to the communities they serve.

The Chairman took part in the Discussion; but as the author was in Australia he was unable to reply.

On the motion of the Chairman a vote of thanks was accorded to the author.

The meeting was then adjourned.

THURSDAY, 5th SEPTEMBER, 1901.

Mr. JOHN STRAIN, Vice-Chairman, in the Chair.

THE PROPOSED TUNNEL BETWEEN SCOTLAND AND IRELAND."

Paper by JAMES BARTON,

Abstract.

THE important national and local advantages of a tunnel between Great Britain and Ireland are not discussed in this paper, which deals only with the engineering questions involved.

SELECTION OF SITE.

The first question considered is the selection of a site for the tunnel. Three positions suggest themselves. First, the nearest approach of Great Britain to Ireland is at the Mull of Cantyre, where the distance to the Co. Antrim is 12½ miles. The next position in point of distance is from Wigtownshire, where the Scotch coast comes within 21 to 25 miles of Ireland. The third position is from Holyhead to Howth.

The maximum depth of water on the Cantyre route is 460 feet; on the Wigtownshire route the depth varies according to the line selected, and is from 480 to 900 feet; and the greatest depth on the Holyhead route is 432 feet.

The strata of the Cantyre route are lower Silurian; on the Wigtownshire route to Antrim, Silurian for the most part, but overlaid near the Irish coast by new red sandstone and the Keuper marls; between Wigtownshire and the Co. Down, lower Silurian throughout; from North Wales to Dublin would be in the Cambrian rocks.

The first of these positions has to be abandoned on account of its not forming a practically useful connection.

The second forms a direct line between Carlisle and Belfast, the business centre of Ireland, and gives the best route from Scotland to all Ireland, and for the North of England to Ireland.

The third route would connect London best with Dublin, but would be of little use as between Scotland and Ireland, and being more than double the length of the second route, it has to be abandoned, and the second route adopted for the present project.

LOCATION.

On the second route two lines are considered—one from Portpatrick, Wigtownshire, to Donaghadee, Co. Down; the other from near Corsewall Light to the Co. Antrim, with a curve in the centre to pass round the north end of the Beaufort Dyke, a deep valley or gorge in the bottom of the sea, which runs for 30 miles north and south seven miles from the Scotch coast. The channel bed north of this Dyke is comparatively level.

A tunnel under Beaufort Dyke would involve very serious difficulties and probably dangers.

DESCRIPTION OF THE LINE.

The tunnel line adopted begins at the Stranraer Railway Station, and passing north, enters the tunnel at five miles, and, descending 1 in 75, passes under the shore line at the Ebbstone Beacon at nine miles; it passes round a curve of a mile radius at the head of Beaufort Dyke at 16 miles, and reaches the shore line at Island Magee, Co. Antrim, at 34 miles, rising 1 in 75 from the deep water, and passing out of the tunnel at 39½ miles, it joins the Belfast and Northern Counties Railway at 41 miles, and runs 10½ miles along it into the terminus at Belfast,

Total length, Stranraer to Belfast, 51½ miles, of which 34½ is tunnel, and 25 of this under the sea.

To provide suitable drainage the line falls each way from the centre, and drainage headings have to be run to the shafts at each side, where pumping stations would be placed.

Subsidiary shafts are proposed at a short distance inland, and would in connection with the main shafts enable specially accurate lines to be given for the tunnel.

GEOLOGICAL.

The geological formations have been reported on by Professor Hull, late director of the Geological Government Survey of Ireland, and his views of the strata to be met with are indicated on the diagram section accompanying the paper. His views were confirmed my the late Mr. Topley, of the Geological Survey of London.

The top of the tunnel is proposed to be placed 150 feet below sea bottom, and the tunnel is to be for a double line.

The principal operation, and that which controls the time of execution of the whole work, is the heading.

The heading proposed is 10 feet wide by 7 feet high. The heading through the Silurian, should probably be as rapid as those now being made in the Simplon Tunnel; those in the Keuper marls more rapid; and the whole heading can, it is believed, be completed under 10 years, and the finished tunnel between 11 and 12 years.

Improvements in rock drilling in the Alpine Tunnels have been remarkable of late years; the maximum speeds of Alpine tunnels are as follows:—

	Cost of Tunnel per yard complete.
Mont Cenis, maximum speed per day, 6 yds.......	£224
St. Gothard, maximum speed per day, 10 yds....	£142
Arlberg, maximum speed per day, 12 yds..........	£107

The Simplon heading has so far been faster than the Arlberg, and in a very hard rock (specimens of the rock were submitted with the paper); specimens of the rock for the proposed tunnel were also submitted, showing the silurian, sandstone, and Keuper marl.

THE WATER QUESTION.

The amount of water to be dealt with is the one uncertainty, though there are grounds for believing it is not likely to be a very serious difficulty. The Severn and Mersey tunnels encountered no serious water leakage *under the sea*, the great leak of the Severn Tunnel being from fresh water and a quarter of a mile from the sea. Judging from these tunnels, and a tunnel driven under the Forth by Sir Benjamin Baker, there seems good ground for believing that the sea bed under the Irish Channel has probably sealed all interstices, so that excavation may be expected to be fairly dry. Silurian rocks are found in beds nearly vertical, which have been under heavy horizontal pressure, and will probably give little water either in the under sea or approach tunnels; the Keuper marls under the Irish side are remarkably suited to an under water tunnel, being perfectly water-tight where examined down to 900 feet.

The new red sandstone which lies between the marl and silurian allows water to percolate, but is not likely to give large quantity; 150 feet of cover between tunnel and sea bed will, it is expected, make all safe.

The working of the line from Stranraer to Belfast is proposed to be by electric motors from installations near the main shafts, one at each side of the channel; and it is intended that trains be run at a speed of 60 to 70 miles per hour, so that the time of tunnel would be a little over half an hour, and the whole distance traversed (Stranraer to Belfast) under an hour.

VENTILATION.

The ventilation of the tunnel is rendered easy by the use of electric power; a current of fresh air would be sent in by a fan at one end, and drawn out at the other, probably upon the Saccardo system successfully used in Italy.

ESTIMATE.

The cost of the tunnel is estimated by the engineers and by a contractor at 10 millions, exclusive of interest during construction, and this leaves a considerable margin for contingencies. The finance of the project is the present difficulty, the prospect as a speculation not being sufficiently good.

The subject has been brought before the Government as an Imperial one; and a small guarantee asked. Mr. Balfour expressed himself desirous of seeing the project carried out, and was willing, if the amount of capital could be *definitely fixed*, to bring the subject before his colleagues. Until a heading has been run from the Irish side past the junction between the sandstone and silurian, no contractor is willing to undertake the tunnel at a fixed sum; to do this, however, would probably not cost more than half a million, and a heading through the whole 34 miles is estimated at 2½ millions.

The following members took part in the discussion:—Mr. Jas. Mansergh, Mr. F. W. M'Cullough, Mr. Leonard M. Bell, Sir Douglas Fox, Professor C. A. Carus-Wilson, and the Chairman.

The author replied to their remarks, and on the motion of the Chairman was accorded a vote of thanks.

"CHEAPER RAILWAY FARES."

Paper by Horace Bell.

Abstract.

On no subject is opinion so frequently and strongly expressed, both in private and in public, as on the need for cheaper railway fares. It cannot be contended that this is mere British grumbling, since, if it means anything at all, it implies that, on existing conditions, the mass of the people cannot afford to travel as often as they would do on more reasonable terms, or, in other words, on terms more suited to their means. The question is one mainly of third-class fares; for it is from this source that quite 90 per cent. of passenger receipts are derived at the present day. The second class must be regarded as a moribund institution, while the first class is on most lines unremunerative, and is maintained, in great measure, as a politic concession to a small but influential body of customers. The movement in the direction of one class is already well defined. Its complete success, coupled with low fares, on tramways, on omnibus routes, and lately on the Central London Railway, affords unmistakable signs of what we are coming to in the near future, in serving nine-tenths of the travelling public. Yet, in spite of these and other obvious indications of change, our home railways still adhere stubbornly to the "parliamentary" minimum fare of one penny per mile for all but cheap trips and "week-end" excursions, and apparently disregard the broad hint which the profitable results of these deviations from the standard charge afford, viz., that by reducing the ordinary fare to, say, a halfpenny per mile, they would probably, if not certainly, get three persons to travel where they now get but one. They appear to consider the penny a mile as "bed-rock," and that any departure from it is to be regarded more as a benevolent concession, or hazardous, if not reckless, transaction, than as sound and lucrative business. At the time that the "parliamentary" fare was established, now more than fifty years ago, it was vehemently opposed, and mainly on the ground, then largely prevalent, that the "cost of conveyance" was a fixed figure. It was not then seen, as it is now, that, far from being fixed, the cost of moving passengers, or hauling goods, varies up or down with the volume of traffic dealt with. Every tyro in railway policy now knows as the alphabet of his business that if it costs, say, x to move 100 passengers, it does not cost $5x$ to move 500. The penny a mile

has long since been found to spell anything but ruin. No railway manager would for a moment think of increasing it. But how many of them can see the mine of wealth which lies waiting for those who will materially reduce it?

The absence of systematic and detailed statistics for the railways in the United Kingdom in a large degree accounts for the timidity, or we may call it conservatism of their management. There are probably but few of our railway managers who are in a position to unhesitatingly quote the prime cost of moving a passenger or a ton of goods, as derived from the operations of any single year, or could do more than guess at the cost of running expenses per train mile; while the outlay per passenger-mile or per ton-mile, which would include charges shown separately for each department, would be to him no more than as a dream of perfection, or perhaps as a nightmare of embarrassment. Yet, if we turn to the statistics annually offered for the American railways, or, better still, for the Indian railways, we find that for each system, under separate administration, there is an invaluable review of its yearly operations, in every detail, and for each department, and in a form so clear as to render the results on any one line readily comparable with those of another. It is due in great measure to these statistics that the rates and fares on Indian railways are probably the lowest in the world, and at the same time eminently profitable. Taking as an instance the East Indian Railway, the figures for 1899 show that in this year the line carried a total of 18½ million passengers, of which 17 millions were of the third or lowest class; that the average number of passengers in a train of all classes was 228; the average distance travelled was 61 miles; the cost of hauling one passenger one mile was one-eighteenth of a penny, and the fare charged one fifth of a penny per mile—all debits included. Now, it may be readily allowed, in comparing the fixed charges (for operation only), and the running charges on this line, with those of some of our leading English lines, that the East Indian has some points in its favour; but these, after all, are as nothing in face of the fact that if the average income of the third-class passenger in England is taken, say, at £15 a month, that of the same class in India may be taken, and liberally, at no more than 15 shillings; that is to say, that in order to induce any passenger traffic at all, and one that was worth considering, the Indian railways have had to come down to rates which the English railway manager would have imagined impossible. They have found, however, that by moving very large numbers at very low fares, the result is most profitable, and, in face of such figures as are given above, it is but reasonable to ask whether the penny a mile must be continued as the standard fare in the United Kingdom, *i.e.*, for ordinary journeys. The reply might be that the penny pays, and that any materially lower fare may not. Yet against this we have the fact that fares approximating to a halfpenny a mile, or indeed less, on the Central London, the District Railway, and the Glasgow Tramways, are, with large numbers, not only possible in a fiscal sense, but that, in the face of keen competition, it is the only way of getting the traffic. From such facts it seems fair to expect that if the halfpenny a mile was adopted generally on English railways, for all journeys, instead of the penny, thousands, or rather millions, would largely increase the number of their railway journeys, and that, moreover, an entirely new stratum of travellers would be reached. It is further to be remembered that a development of passenger traffic is now well understood to bring with it a corresponding improvement in goods traffic.

It is not overlooked that the settlement of this question is no small matter, for it must be tested fairly, and on a sufficiently large scale, while the experiment may, or perhaps must, involve a considerable expenditure on additional rolling stock for at least main lines. The area on which the experiment would seem at first most likely to prove successful is on the railways serving the seaboard round London. There lies a field for the enterprising manager such as exists nowhere else in the world—a city of, let us say, five millions of sea-loving people at one end, and the sea at the other. Yet there we find, at any rate for the third class passenger, a poor and unpunctual service; a class of rolling stock which, until quite lately, was almost the worst in the country; and fares which, to the bulk of the people, make a visit to the seaside a rare luxury, while it should, and could, be the commonest holiday jaunt for the Londoner. With fares reduced to a halfpenny a mile, with a fast direct service, and with ordinarily decent carriages, thousands upon thousands of people, who now perhaps go down to the sea once in the year, would come to regard such a trip with but little more hesitation than those who now fill the Pullman cars to Brighton and elsewhere. What can be more obviously prohibitive to the great lower and lower middle class than the present ordinary return third class fares to Brighton (8s 5d), to Dover (12s 11d), to Margate (12s 4d), or Hastings (10s 1d)—all at the inevitable penny a mile, and none of the places much more than 70 miles from London. At a halfpenny rate, and with an ample service of quick through trains, the present passenger traffic could probably be quadrupled, more especially if facilities for through booking were arranged with the District Railway; indeed, it is more than likely that it would pay to make entirely new direct lines, electric possibly, for no other purpose than to serve a through passenger traffic between London and the sea coast. But for the railways round London, at least, the halfpenny fare need not be confined to seaside traffic. It would effect a great development of suburban traffic, more especially on the shorter distances, and induce a far greater movement of the rural population to and from towns and villages from distances of 50 to 60 miles from the metropolis, a movement which is now inconsiderable, and which would well repay better attention on the part of railway men.

Conservatism appears to be the key-note of the policy of our railway companies. They seem to say—"Our officials and our work-people get their pay, the board gets its fees, and the shareholders their moderately good dividend. What more do you want?" The "more" that is wanted is some attention to the claims of the British public, more regard for the interests of the shareholders, some attempt to shake off old-fashioned ideas, and to strike out in new directions. In any such attempts they should recollect that every small advantage which the third-class passenger now has, as compared with his position 50 years ago, has been simply wrung from the companies against their vehement opposition, and yet not one of these would now think for a moment of returning to the old regime. The "parliamentary" train was discouraged by making it almost impossible for the third-class passenger to effect any long journey in daylight, even although he was expected to start at cock-crow, and was made to get out and wait at junctions; though even when his train arrived there might be no room for him. Conveniences of any kind, even for refreshment, were not even contemplated for this lowly type of traveller. Again, when the Midland Company, in 1872, boldly started to carry third-class passengers by all trains, the other companies, especially the Great Western, lagged behind for a long while, and even to this day the South Eastern and Chatham companies run some trains either with first and second only, or with an extra charge for third class. Again, the substitution of two classes for three, proposed or advocated by Mr. Gladstone so long ago as 1874, which has already been amply proved to be both politic and profitable, has not as yet been adopted generally, though it grows slowly. So it is with the reduction of fares; the fare and a half, and the single fare—or, in other words, the halfpenny per mile—are already well to the front for trips and excursions, but for these only, though they show without doubt that full trains at these rates are distinctly remunerative. There are, in fact, but few lines on which the actual cost of carrying passengers in full trains can be much more than half a farthing per head per mile, yet, though our railways have taught us to travel, they have not learnt their own lesson, which is to offer the necessary inducements to extend the habit. They go on with the same old "penny a mile," as if there was divine revelation in the figure, and as if our railway boards were not men of business but mere ornamental pluralists. In some cases, if not in many, the boards are held down by the inertia of their managers, as was notoriously the case on the Great Western, when in the able but very conservative hands of Grierson. His type is unfortunately still too common, and for the reason that by the time a man has worked up from the bottom of the ladder to the position of manager, he has too generally and not unnaturally lost his vigour and the spirit of enterprise. His policy is to let well alone. The better or the best may be left to others to try for. On the other hand, there are doubtless many younger men who, if given reasonable latitude of action, would soon show that the true policy of the administration of a railway is, as much as in any other industrial undertaking, to venture, to move forward, even if slowly, and to be content, not merely when they have met a demand forced on them, but when they have introduced facilities which will induce a further demand.

One acknowledged difficulty in carrying out a general and considerable reduction in third-class fares lies in the want of sufficient yard and platform accommodation at many of the older principal stations, and especially in London, if, as is almost certain, the halfpenny per mile fare led to trebling the number of travellers in the third class. At many of the smaller stations, as, for instance, on the Brighton and the South Eastern and Chatham lines, the same difficulty would be experienced, though this difficulty is after all almost entirely one of money, and is one that can be met gradually and tentatively as the demand develops. A similar but probably less immediate obstacle will be found in the need for a large increase in the rolling stock. But neither these nor other difficulties would stand in the way for long when experiment had satisfactorily established that the reduction of fares would be profitable.

Mr. R. Elliott Cooper, Sir Guildford Molesworth, Sir William Preece, and the Chairman took part in the Discussion.

On the motion of the Chairman a vote of thanks was accorded to the author.

On the motion of the Chairman a vote of thanks was accorded to the Honorary Secretary; and on the motion of Mr. C. P. Hogg, a vote of thanks was accorded to the Chairman.

The business of the Section was then brought to a close.

SUMMARY OF PROCEEDINGS

OF

Section II.
Waterways and Maritime Works.*

TUESDAY, 3rd SEPTEMBER, 1901.

Sir JOHN WOLFE BARRY, K.C.B., LL.D., F.R.S., in the Chair.

The Chairman in opening the Proceedings of the Section cordially welcomed in name of the British representatives of Engineering their confrères from every part of the world.

"THE DORTMUND AND EMS CANAL."

Paper by REGIERUNGS und BAURATH HERMANN.

Abstract.

THE Dortmund and Ems Canal connects the industrial regions of Rhineland and Westphalia with the North Sea. It begins at Dortmund and Herne, and ends at Emden. The distance between the two termini is 270 kilometres (168 miles). The canal is 2.5 metres (8 1-5th feet) deep, and 18 metres (59 feet) wide at the bottom. The locks in the upper reaches between Dortmund and the 138 kilometre post (about 85 miles) have an available length of 67 metres (220 feet), and are 8.2 metres (27 feet) wide. Barges of this length, and having the permissible maximum draught of 2 metres (6 feet 7 inches), can carry about 1000 tons. On the lower reaches the locks are 165 metres (542 feet) long, and can accommodate a whole train of barges. The water-level in the summit reach (15.5 kilometres—9½ miles—long) at Dortmund is 70 metres (230 feet) above zero (zero equals zero of the Amsterdam standard gauge). Barges are lowered from this level to the main reach below, 67 kilometres (41⅔ miles) long, by a canal lift at Henrichenburg. The next lock is at Munster, and has a fall of 6.20 metres (20⅓ feet); by its aid barges reach the Midland Reach, which is about 37 kilometres (23 miles) long. The reach is so

---

* The proceedings of Section II. are published in full by Messrs. Wm. Clowes and Sons, Ltd., Duke Street, Stamford Street, London, S.E., price 6s. 6d. post free.

called because, from its northern end, immediately before the lock, the Midland Canal is about to start, leading to the Weser and the Elbe without any change in the water-level, which is 49 metres (161 feet) above zero. When carried out, there will be a reach 210 kilometres (130½ miles) long, without a single lock, between Munster and Hanover. Between the Midland Reach and Meppen, there are eleven locks to pass through. Beyond Meppen, the River Ems forms the sole waterway, and is divided into five lengths by as many locks. From Oldersun, at 10 kilometres (6 miles) above Emden, a lateral canal, skirting the Ems, leads by means of two locks to the inland port of Emden.

Altogether there are 20 locks between Dortmund and Emden, representing a total fall of 70 minus 1.138 metres (Emden inland gauge), or 68.862 metres (226 feet). The smallest radii of curvature on the canal are 400 metres (20 chains), and on the River Ems, where the bottom width is 30 metres (98½ feet), 350 metres (17½ chains).

There are one hundred and seventy-five bridges leading over the canal. Only two of these are movable; all the others are fixed, and have a free headway of 4 metres (13⅛ feet) above the highest water-level. The canal crosses the Rivers Lippe, Stever, and Ems, on massive aqueducts, 18 metres (59 feet) wide. All slopes of the canal that are cut through any formations that are not compact enough in themselves to withstand the wash of the waves, are protected with stone pitching or cement concrete slabs. The covering is carried 0.60 metre (2 feet) below, and 0.50 metre (1⅝ foot) above the water level. The canal is made water-tight on all high embankments by a layer of clay to prevent leakage. The thickness of this layer varies from 0.30 to 1.00 metre (1 foot to 3 feet 3⅜ inches). The bulk of the water for feeding the canal is pumped from the River Lippe. The balance of the supply is derived from the natural drainage of only 60 square kilometres 23.17 square miles). The loss of water in the canal, from all causes, amounts to 10.4 litres per kilometre (3.68 gallons per mile) per second, according to observations made to date.

There are three pumps in use, each of 400 H.P. The height to which the water is raised is 15.75 metres (51⅔ feet). To be able to sub-divide the long reaches of the canal into short lengths, in the event of sudden accidents, stop-gates of a novel design have been provided, which can be turned either way, and are able to withstand the full head of water in either direction. Each gate consists of a single web plate of mild steel, which is bent in the shape of a segment of circle, and is properly stiffened by suitable frame-work. The gate is raised out of the water by means of a pair of long lattice-work arms or spokes, carried by trunions, which revolve in bearings bedded in the side walls of the passage. The arms are set in motion by capstans. When not in use the gate is held up by the arms across the canal, like a hood or shield.

The canal lift at Henrichenburg is constructed on the principle of a floating trough moving in parallel guides. The whole weight of the trough full of water is carried by five floats, which move up and down in as many wells. The whole system is in equilibrium, so that any addition to the volume of water in the trough makes this sink, and, *vice versa*, any reduction in the volume causes the trough to rise. The up or down movement is controlled by four screw spindles, which work in four nuts, which are attached to the cradle carrying the trough, and are simultaneously raised by the turning of the spindles.

The power is transmitted by electricity. There are two dynamos in the central station, of 220 H.P. each. The tension is 220 volts, and a current of 800 amperes is required for starting.

The principal posts along the canal are Dortmund, Herne, Munster, and Emden; and there are also about seventy smaller ports or landing places, which are distributed over the whole length of the canal.

At Emden, there is an open harbour outside the lock, in addition to the inner harbour, for the accommodation of sea-going vessels up to 6.5 metres (21⅓ feet) draught. At average tide, there is a depth of water of 10 metres (33 feet) in the sea channel. The range of the tide is 2.90 metres (9½ feet). The outer harbour is most completely equipped with cranes, warehouses, railway lines, and an electric coal tip, and has already been opened for traffic. The port at Dortmund has been built by the town at a cost of 5.5 million marks (£275,000).

The total cost of the canal amounts to 79.43 million marks (£3,971,500), or to about 316,000 marks per kilometre (£25,438 per mile).

The canal lift at Henrichenburg cost 2.6 million marks (£130,000). A lock, built in masonry, of 165 metres (572 feet) available length, cost 500,000 marks (£25,000); one of 67 metres (220 feet) length, 310,000 marks (£15,500); a needle weir 170,000 marks (£8,500); the aqueduct across the River Lippe 650,000 marks (£32,500); and a small steel-girder bridge 25,000 marks (£1250).

The barges are drawn along the canal by tugboats, or are towed by a rope from the towing path. All establishments are ready for the adoption of electric towage, which is to be introduced so soon as the volume of traffic has increased sufficiently to make it a matter of necessity to adopt a systematic and properly regulated traffic of barges. The speed of navigation has been fixed at 5 kilometres (3 miles) an hour for vessels drawing 1.75 metre (5¾ feet), and at 4 kilometres (2½ miles) an hour for vessels drawing 2 metres

(6 feet 7 inches). The screws of steamers must remain 0.75 metre ($2\frac{1}{2}$ feet) above canal bottom.

The volume of traffic on the canal is considerably increased by the sea-going lighters of from 400 to 800 tons carrying capacity, which frequent it from all parts of the Baltic and the North Sea. They are towed from Hamburg, Bremen, and elsewhere, to Emden, and most frequently go up the canal without unloading any part of their cargoes.

The canal tolls are at present levied upon goods divided into three classes, and amount to 10, 25, and 50 pfennig (1d, 2d, 3d, and 6d) per metric ton for the whole canal length, and less in proportion for shorter distances).

The principal goods imported are Swedish ores from Lulea and Oxelsund, corn, and timber. The bulk of the export goods consists of coal and iron.

The canal was completed in 1899. Last year half a million tons were carried along it. For the current year a substantial increase may be reckoned upon in the tonnage.

The following members took part in the Discussion:—Prof. V. E. De Timonoff, Mr. W. H. Hunter, M. Mendes Guerreiro, Mr. Wilfrid Stokes, and the Chairman. The author replied, and on the motion of the Chairman a vote of thanks was accorded to him.

"NOVEL PLANT EMPLOYED IN TRANSPORTING THE EXCAVATIONS ON THE CHICAGO DRAINAGE CANAL WORKS."

Paper by ISHAM RANDOLPH.

Abstract.

THE paper gives an account of the sanitary history of Chicago up to the appointment in 1889 of the first Board of Trustees of the Sanitary District. To improve the sanitation, it was decided to cut a channel across the divide which separated the watershed of the Chicago basin from that of the Desplaines and Illinois valleys, whose slope is towards the Mississippi River.

The channel, as now in use, is described under three divisions: —The first division extends through a clay formation for 7.8 miles, and has a bottom width of 110 feet, with side slopes of two to one, giving, with the minimum depth of 22 feet, a width at the waterline of 198 feet. This section is to be widened by dredging, to afford the full flow of 600,000 cubic feet per minute, and the bridges are all built of a span to admit of this enlargement.

The second division is through glacial drift for 5.3 miles; it is 202 feet wide at the bottom, has side slopes of two to one, and with the minimum depth of 22 feet, has a width of 290 feet at the waterline. The gradient through these two divisions, 13½ miles long, is 1 in 40,000.

The third division, beginning at Willow Springs, is through rock, or rock overlaid with glacial drift. The length is 14.95 miles, about seven of which are through rock-cuttings of an average depth of 36 feet; it is 160 feet wide at the bottom, and has vertical sides, with two offsets of 6 inches each on each side, giving a resulting width of 162 feet at the water surface. The gradient through this division is 1 in 20,000 feet, and the total length of the main channel proper is 28.05 miles. It discharges into the Desplaines River at Lockport, and the overflow is controlled by regulating works, consisting of seven steel lifting gates of the Stoney free-roller type, each 32 feet wide, and one bear-trap dam, 160 feet wide, having an oscillation of 17 feet.

The volume of material excavated from the main channel, and for the diversion and enlargement of the Desplaines River, amounts to 29,246,838 cubic yards of glacial drift, 13,106,586 cubic yards

of solid rock, and 1,382,195 cubic yards of earth—or a total of 43,736,379 cubic yards. The work, for convenience in designating the several contracts, was divided into sections, each approximately one mile in length (there were 29 sections in 28.05 miles). On this work there were seventeen contractors. The main channel is spanned by thirteen bridges, all movable structures, six of which are for highways and seven for railways. The cost of all this work, including 7000 acres of land, interest account to January 1st, 1901, administration, and all other items, amounted to £7,329,633.

The dredgers used for excavating the Chicago River on the first section west of it were of the ordinary type, the only novelty about them being the substitution of wire cable for chain cable on the cranes. The dippers of some had a capacity of six cubic yards. Most of the sections were excavated by dry methods. Hydraulic dredgers, one of which cost £8333, were used for two of the sections. These dredgers were equipped with four 100 H.P. horizontal boilers, a 250 H.P. Westinghouse engine, a 6-foot centrifugal pump, with a 20-inch suction pipe and an 8-inch steel discharge pipe. The suction pipe had flexible joints, and at its extremity a revolving cage with knives to erode the material to be excavated. The material eroded by the revolving knives at the end of the suction pipe was drawn in with the water and discharged into settling basins, some of which were situated a mile away. The best performance of either dredger was 11,000 cubic yards in 24 hours.

Ploughs and scrapers drawn by horses, and steam shovels of various types, were used for removing top soils. The "New Era" grader was employed by some of the contractors. It is a great breaking plough, drawn by 12 to 16 horses, and will excavate about 100 cubic yards per hour in friable soils.

The Heidenreich Incline Conveyor was among the most successful devices used for delivering the excavated material on to the spoil area. Its best record was 968 cubic yards per shift of ten hours. This device consists of a framework, mounted upon trucks, which travels on tracks parallel with the channel. In elevation the framework is a triangle with one side as the base, which carries engine, boiler, dynamo, and hoisting machinery. The other side points upwards, and projects beyond the base, and the third side forms the roadway which carries two standard gauge tracks, on which the cars for loading and dumping alternately are moved. The top section of the track, for a length of about ten feet, is pivoted, and forms a tipple, so that when the loaded car is drawn up from the pit, as soon as its centre of gravity passes the axis on the tipple, it is thrown forward and its contents dumped. As soon as it is empty, the counter-weighting of the tipple causes it to right itself, and the empty car is returned to the pit. Meanwhile the car on the other track has been loaded, and is being hauled up. The Christie & Lowe Conveyor, also used on this work, is a modification of the above.

Mason & Hoover's Conveyor is a bridge spanning the channel, with a cantilever arm extending over the spoil area; it is carried on trucks which travel on tracks parallel to the channel. The bridge carries a steel belt, 1300 feet long, made in 4-foot sections, interlocking and hinged with 2-inch axles, carrying 12-inch flanged wheels. This belt works in a metal trough with rails on each side, on which the pan wheels travel. A separate car carries two boilers, which supply steam for running the conveyor, and also for propelling the plough which loads it. The latter can be drawn back and forth across the channel without turning, and cuts a furrow each way. The conveyor is driven at the rate of 120 feet per minute; the plough is started at the top of the cut, and the successive furrows are lower and lower, until the bottom is reached, and the material thrown from the ploughshare rolls down the side of the cut on to the conveyor; its best record achievement for any month was 509 cubic yards per 10-hour shift.

Bates' Conveyor consists of a car with boiler and necessary gearing for driving the conveying belt. The car moves parallel with the channel; a frame extends down from the car into and across the channel excavation, carrying at short intervals concave rollers, on which a roller belt, 22 inches wide, travels. This belt passes under a hopper, in which a pair of cylinders set with great steel knives, which intermesh, revolve, and break up the clay which is dropped into the hopper by the steam shovel. The granulated material is delivered on the belt, and carried up over the power car, where it is delivered on to another similar belt, carried on a bridge which spans the spoil area; its best average for one month was 920 cubic yards per shift.

In the rock sections, the sides were cut down vertically by channelling machines. These consist of boiler and engine and channeller, or large Z-shaped chisel made fast to the end of the steam piston-rod. Each machine will cut about 100 superficial feet per 10-hour shift.

The Lidgerwood Cableway proved a very efficient conveyor. The carrying cable is stretched across the channel from the tops of supporting towers, which span the channel and the spoil area. The towers are mounted on wheeled platforms, which run parallel to the channel. The cable carries a cage, and draws it back and forth. When the skip has been loaded, lifted out of the pit, and run out to the spoil bank, the dumping cable, which is wound on the same drum with the hoisting cable, and travels at the same speed, is, by means of a lever, thrown on to a drum of greater diameter, which winds it up more rapidly than the lifting cable, and tips the skip forward, discharging its load. The empty skip is then returned to the pit, and a loaded one removed. The average performance was about 400 cubic yards per day.

Brown's Cantilever Conveyor proved wonderfully efficient in handling blasted rock, and had the best record of any device on the work. It is essentially a platform, about 40 feet square, carried on four sets of trucks, supporting the four corners, which travel on two tracks parallel with the channel. The platform carries the operating machinery. A steel tower, composed of four braced and stayed corner posts, with sides of unequal height, supports in equilibrium a bridge, 355 feet long, on an angle of 12 deg. 50 min. to the horizon. This bridge carries a track on which a trolly car runs, which is hauled up and down its length of travel by an endless cable. The time consumed in lifting a skip, running it off, dumping it on to the spoil bank, and returning it to the pit, is about 50 seconds. The excavation is made across the channel, giving a working face corresponding with its width. The skips or hods have a capacity of 75 cubic feet, or about 7500 pounds, of broken limestone.

The High Power Derricks used on one of the sections were very ponderous and powerful. They are mounted on turntables self-poised, and have double booms, which counterbalance each other. They move on rollers and work in pairs, one on each side of the channel, as the booms would not reach across the excavation. Their performance did not fulfil expectations, their best record being 372 cubic yards per shift of 10 hours.

This gigantic work is bound to exercise a wonderful influence as an educator, and embolden men to undertake enterprises more vast than were considered practicable before its success had been demonstrated. The great array of mechanism brought into being for its construction, which earned vastly more than it cost to produce, was, most of it, without a sphere of usefulness after the work was completed, and was dismantled and sold for the value of the raw material.

As a corollary to the work already done, the Chicago River, which is the main artery of supply for the Sanitary and Ship Canal, is now being widened and deepened.

The following members took part in the Discussion:—Mr. W. H. Hunter, Mr. Andrew Brown, Mr. George Higgins, Mr. Charles H. Whiting, Mr. A. W. Robinson, and the Chairman.

On the motion of the Chairman a vote of thanks was accorded to the author.

"IRRIGATION IN THE NILE VALLEY AND ITS FUTURE."

Paper by W. WILLOCKS, C.M.G.

Abstract.

THE ancient basin irrigation of Egypt, which utilises the flood waters of the Nile, is a system of irrigation eminently suited for new countries whose permanent development depends on irrigation. The history of the development of the basins in Egypt is here traced. The work was successfully begun on the left bank of the river in the time of King Menes, and extended to the right bank by the great Pharaohs of the XIIth. Dynasty, who converted the Fayoum depression into Lake Moeris.

The value of subsoil water is next dealt with. It supplies the link between basin and perennial irrigation. The foundation stone of the conversion of the whole of the Egypt from basin to perennial irrigation was laid by Mehemet Ali in 1833, when he began the construction of the barrages across the Nile branches north of Cairo. The accumulating of silt in the canals forms a serious drawback, and the best method of dealing with it is considered. The necessity of providing suitable manures is also dealt with. The cost of the different schemes is fully given.

The modern irrigation works are the Cairo and Subsidiary Barrages, the Assiout and Zifta Weirs, and the still more recent reservoirs. The history of the Assuan reservoir and dam is given from the inception of the scheme up to the present day. The action of the Government with regard to Philae Temple is criticised.

The paper closes with outlines of schemes for irrigating the whole of the Nile Valley, by possible reservoirs in Abyssinia and Uganda; and the possible development of the Sudan, when Egypt is perennially irrigated, is portrayed. Strong brigades of canal engineers are required to work up projects in the Sudan, which, although a poor country in itself, is of inestimable value to Egypt as a highway for the waters of the great lakes.

Prof. Vernon Harcourt, Mr. Wilfrid Stokes, and the Chairman took part in the Discussion. The author replied by correspondence.

On the motion of the Chairman a vote of thanks was accorded to the author.

The meeting was then adjourned.

WEDNESDAY, 4th SEPTEMBER, 1901.

Sir JOHN WOLFE BARRY, K.C.B., LL.D., F.R.S., in the Chair.

"PROPOSED INLAND WATERWAY BETWEEN THE BALTIC SEA AND THE WHITE SEA."

Paper by Professor V. E. DE TIMONOFF.

Abstract.

THE north-western territories of Russia can be compared with those of the Great Lakes of North America. A glance at the map of this region will show the similarity at once. Lakes Ladoga, Onega, Saïma, Ilmen, Peipous, and others, which receive the waters of many important rivers, are situated in the principal low-lying regions. Most of these lakes belong to the basin of the Neva, and form an extensive navigable system. The superficial area of the basin of the Neva is 288,972.5 square kilometres (111,572.4 square miles).

Lake Ladoga has an area of 18,129.6 square kilometres (7000 square miles), and a coast line of 1142 kilometres (709 miles). Lake Onega has an area of 9751.1 square kilometres (3765 square miles), with a coast line of 1300 kilometres (807 miles). Lake Wygo, situated on the dividing ridge between the Baltic and White Sea basins, is 80 kilometres (58 miles) long, by 5 to 32 kilometres (3 to 20 miles) wide, and has an area of 929 square kilometres (358.68 square miles).

These three lakes indicate the natural route from the Baltic to the White Sea. The greater part of this route, even independently of the lakes themselves, comprises very important natural navigable waterways. Lake Ladoga is connected with the Baltic Sea by the river Neva, and with Lake Onega by the river Svir. Again, the upper reaches of the river Poventchanka, which flows into the northern end of Lake Onega, are close to the basin of Lake Wygo, which is itself connected with the White Sea by the river Wygo. In fact, with the exception of less than 10 kilometres (6 miles), which will have to be rendered navigable, the whole route from St. Petersburg to the White Sea—a distance of over 900 kilometres

(558 miles)—is navigable. Two of the rivers in the above navigable system have a very large discharge.

The depth of the Neva varies from 20 to 40 feet throughout the greater portion of its length, and is as much as 59 feet near St. Petersburg. There are very few natural obstacles to navigation. The Svir is nowhere less than 1.6 metre (5.25 feet) deep, on a length of 210 kilometres (130 miles). In order that vessels drawing 14 feet may be able to enter Lake Ladoga, a few hundred thousand cubic metres must be dredged from the bed of the Neva and at its outlet from the lake, involving an outlay of barely half a million francs (£20,000). By increasing the expenditure to one million francs (£40,000), the lake could probably be made navigable for ships drawing 20 feet. For this small outlay, Lake Ladoga would become, to all intents and purposes, a part of the Baltic Sea, though it would only be accessible to ships able to pass the bridges at St. Petersburg. The reconstruction of the navigable channels past these bridges is, however, merely a question of time and money, and it should be undertaken without delay, so that ships drawing 28 feet may enter the Neva, this increased depth being already decided upon as regards the Kronstadt Ship-Canal. A few million francs would cover the cost of the necessary works on the Neva, and at the entrance to Lake Ladoga, to render the latter accessible to ships of that draught. The results of opening Lake Ladoga to maritime navigation would be of great importance and of immediate benefit.

The opening of Lake Ladoga to the mercantile marine, though important in itself, would only be the first stage in carrying out the great scheme of connecting the Baltic with the White Sea by means of an inland waterway. The two other stages would be—(*a*) to deepen the river Svir, and to open Lake Onega to maritime navigation; (*b*) to connect Lake Onega with the White Sea by means of a ship-canal.

The second stage presents much greater difficulties than the first. It entails the construction of several weirs, with sea locks, on a large and rapid river. But the advantages reaped by opening Lake Onega to international traffic, and by making a seaport at the mouth of the Vytegra, thus shortening the transit of goods by river barges on the Volga by several hundred kilometres, would more than compensate for the cost of the undertaking. Finally, in order to establish maritime communication between Lake Onega and the White Sea, it is necessary to carry out works of the magnitude of those executed for the Manchester Ship-Canal, for the Kiel and Corinth Canals, and to embark on a proportionate expenditure. These works would, however, be the crowning achievement of the enterprise.

These are the principal features of the scheme.

The project also includes the construction of maritime ports on Lake Ladoga at the mouth of the Svir, and on Lake Onega at the mouth of the canalised river Vytegra, which would be the points of transhipment between the maritime traffic and the river traffic of the immense basin of the Volga. The scheme also includes the construction of a railway which would connect Moscow with the seaports which it is proposed to build at the outlet of the new canal on the White Sea and on the coast of the Arctic Ocean near Norway, where the sea is always free from ice.

The author's scheme fulfils two important objects. In the first place, it will give to the Russian Navy a freedom of action it does not possess at present. The Russian Navy consists of five squadrons, namely, the Pacific Ocean Squadron, the Black Sea Squadron, the Baltic Squadron, the Caspian Sea Squadron, and the Arctic Ocean Squadron. These squadrons would not generally be able to join forces in time of war, as the outlets of the Black Sea and the Baltic could be easily blockaded, and the principal fleets reduced to inaction. This state of things is the more serious, as all the naval and shipbuilding yards and arsenals, etc., are actually situated on these inland seas—namely, the Black Sea in the south, and the Baltic in the north. If the author's scheme is carried out, the Baltic fleet will be in a position to steam to any part of the globe at a few days' notice, before any obstacle can be placed in its way.

The other object which will be attained by the proposed waterway is the industrial and commercial development of Northern Russia. The new waterway will certainly be an important route for conveying to Europe the wood, coal, naphtha, iron and other riches abounding in the northern provinces of Russia.

In terminating this paper, the author states some of the general conclusions which may be deduced from his paper:—

(1) A seaport, situated at the entrance of an important inland waterway, should not be designed and constructed in a manner which may impede the development of the waterway. Furthermore, it is desirable that all possible steps should be taken to avoid the necessity of constructing fixed bridges, or, if these are indispensable, the opening spans should be suitably situated, and should afford ample width and depth between their piers so as to provide for all possible future requirements of navigation.

(2) The development of inland waterways, with as great a depth as practicable, should be promoted, so as to enable ships to penetrate into the heart of the country. To bring this about, it is desirable that those great lakes near the sea, which have sufficient depths for maritime navigation, should first be opened up.

(3) It is desirable that the seas on the coast of the same country

should be connected by deep navigable waterways passing through the country. The construction of those waterways, which serve the double purpose of commerce and national defence, should especially be undertaken.

(4) Any scheme for the formation of an inland waterway of sufficient depth to enable shipping to penetrate into the interior, should provide, as far as possible, for the work to be carried out in sections, so that each section, as it is finished, may be capable of being utilised for navigation, without waiting for the final completion of the undertaking.

(5) In Russia, the inland waterway which fulfils the above requirements is the one which would connect the Baltic to the White Sea by way of the great lakes of Ladoga and Onega. The work might be carried out in three sections, the first being the opening of Lake Ladoga to maritime navigation, the second the opening of Lake Onega to maritime navigation, and the third the junction of the two seas. The completion of each of these stages of the work would bring about great industrial and commercial progress to Russia and to the whole of Europe.

The following members took part in the Discussion:—Baron Quinette De Rochemont, Mr. W. H. Hunter, Mr. William Brown, Mr. S. Mavor, Mr. C. H. Moberley, and the Chairman. The author replied, and on the motion of the Chairman a vote of thanks was accorded to him.

"THE IMPROVEMENT OF THE LOWER MISSISSIPPI RIVER."

Paper by J. A. OCKERSON.

Abstract.

THE Mississippi River is 2500 miles in length, and its drainage area covers 1,256,000 square miles. The regulation and control of a stream of such magnitude involves problems which greatly tax the ingenuity and skill of man to solve. In the lower half of the river the extreme oscillations of stage between low and high water amount to 53 feet; and the volume fluctuates from 65,000 cubic feet per second at extreme low water, to two million cubic feet per second at flood stages. This portion of the river flows through an alluvial bed of its own formation, and the banks are constantly being eroded by the action of the current. This erosion, coupled with the suspended matter brought down by the tributary streams, furnishes the material for sand bars, which at low stages become formidable obstructions to navigation. The regulation and control, then, involve two distinct problems: one the control of floods, and the other the improvement of navigation. Incidentally, the works constructed for flood control have considerable influence on the channel, by preventing a dispersion of the waters and thus inducing a scouring effect which tends to produce uniformity in depth.

The erosion of the banks reaches enormous proportions. In the 885 miles of river lying below the Ohio River, it amounts to an average of 9½ acres for each mile of river each year, or a volume of 1,003,579 cubic yards each year for each mile of river; or a total annual erosion in this 885 miles amounting to ten square miles 86 feet deep.

The alluvial basins subject to overflow cover an area of about 30,000 square miles. It has a soil of remarkable fertility, capable of sustaining a large population. In order to utilise this land, it must be protected from the ravages of the floods. This is accomplished by means of levees, or earthen embankments, built as near the river as consistent with the stability of the banks. At the present time, there is a total length of about 1450 miles of levee. The average height is something over 12 feet. The levees are built with a crown of 8 feet, and side slopes of 3 to 1. High

levees are reinforced with a banquette of earth on the land side. The whole is sodded with a very tenacious grass, known as Bermuda grass. About fifty million dollars (over £10,000,000) have been spent on the levee system, and much work remains to be done before it is completed.

The interruptions to navigation due to low water cover a period of about three months in each year. During the greater part of the year, depths of 14 feet, under natural conditions, can be relied upon; furthermore, the obstructing bars cover only a small portion of the total length. To open channels through these bars, hydraulic dredges of large capacity have been designed, and have been used to good effect. It seems certain that a channel of nine feet or more can be maintained, under the most unfavourable conditions, by this means. The essential features of such a dredger are a double suction centrifugal pump, with runner of 7 feet or more in diameter; a water-jet agitator to loosen up the material; a floating discharge pipe about 32 inches in diameter; suitable winches for manipulating the dredger and suction; motive power and paddle wheels for moving the dredger from point to point under its own steam; all mounted on a steel hull carrying the boiler, machinery, and a cabin for housing the same, and the crew which operates the dredger. There is also a well-equipped machine shop for making repairs, an electric light and refrigerating plant, steam steering gear, and other accessories. These dredgers have a capacity of about 1000 cubic yards of sand per hour, delivered through 1000 feet of discharge pipe. They have been in operation for several years, and are regarded as successful. Dredging in a stream with sand bars that shift more or less with every change of stage, is only regarded as a temporary expedient in aid of navigation, as the flood stages may, and usually do, obliterate the dredged channels; but it serves a good purpose while permanent work is going on.

The permanent work consists of the revetment of banks to prevent erosion, the closure of side channels or chutes, and the contraction of width where the river is abnormally wide. The portion of the bank lying below the low-water line is covered with a fascine willow mat, about 300 feet wide, and made in lengths of 1000 feet or more. This mat is ballasted with stone and sunk to the bottom. As it is always covered with water, the willows are not subject to decay; but the wire which binds the fascines together rusts out in the course of time. To remedy this defect, galvanised and silicon bronze wire is used. After the mat is in place, the upper bank is graded to a slope of 3 to 1 by means of a hydraulic grader, using water jets under a pressure of about 110 lbs. per square inch. The whole surface is then covered with a layer of stone about a foot thick. In some cases concrete, four inches thick, is laid on the graded bank with good success. In the lower sections, where stone is only obtainable by very long hauls, a substitute is found in artificial stone made of thirteen parts of gravel and one of Portland cement.

This work on the Lower Mississippi River is carried on under the direction of a Commission, consisting of four civilian and three army engineers. The author, who is now a member of the Commission, has been connected with the work for some twenty-five years, and so writes with personal experience of the problems involved, and of the methods now in use for the regulation and control of the great river.

Mr. C. H. Whiting, Mr. W. H. Wheeler, Mr. William Brown, the Chairman, and Prof. Vernon-Harcourt took part in the Discussion. The author replied by correspondence.

On the motion of the Chairman a vote of thanks was accorded to the author.

"RECENT IMPROVEMENTS EFFECTED IN THE NAVIGABLE CONDITION OF THE SULINA BRANCH AND OUTLET OF THE DANUBE."

Paper by C. H. L. KÜHL.

Abstract.

THE European Commission of the Danube has been in charge of the Lower Danube since 1856. Training works have been executed at the Sulina mouth, in the Sulina branch, and at the Ismail Chatal. Besides, the Zeglina shoal, above Galatz, has been dredged.

THE SULINA BRANCH OF THE DANUBE.

The navigable depth at zero of the Sulina branch was 8 feet in 1856, 10 feet in 1862, 11 feet in 1863, 13 feet in 1870, 15 feet n 1886, 16 feet in 1889, and 17 feet in 1899. The little M Cutting was opened in 1869.

Since 1880 eight further cuttings have been opened, and a ninth cutting is in progress. 21,690,418 cubic yards have been excavated in these cuttings by three steam dredgers. The different shoals were treated by the construction of groynes and revetments, narrowing the upper part of the Sulina branch to 400 feet and the lower part to 450 and 500 feet. The river has been shortened by seven nautical miles, and when the last cutting is finished the total shortening will be 11 miles.

THE SULINA MOUTH OF THE DANUBE.

The depth of the Sulina entrance in 1856 was from 9 to 7 feet. The provisional jetties started in April, 1858, were finished in July, 1861, when the depth was 17½ feet. The consolidation of the jetties in concrete was finished in 1871, when the depth was 19½ feet; this increased to 20 feet in 1872, and to 20½ feet in 1873. This depth was maintained to 1895 without dredging, with slight reductions only in 1876 and 1879.

The depth of the Sulina entrance being insufficient for modern requirements in 1894, parallel dams, to reduce the width to 500 feet, were constructed between the jetties, and a powerful marine hopper bucket dredger was built.

Dredging was started on the 1st October, 1894, increasing the depth to 22 feet in January, 1895; to 23 feet in August, and 24 feet in September of the same year.

In 1897 the depth was reduced to 23½ feet from the 6th March to the 17th April, during a heavy river flood, bringing down much sediment. Since that time the depth of 24 feet has been maintained, the quantity dredged from 1894 to 1899 being 1,790,736 cubic yards.

The practical result of these works is that the size of steamers navigating the Sulina branch has increased from the maximum of 1462 net reg. tons in 1880 to 2889 net reg. tons in 1900; and for the port of Sulina the maximum of 2190 net reg. tons in 1892 has been increased to 3519 net reg. tons in 1900.

M. Vander Vin, Prof. Vernon-Harcourt, Mr. W. H. Hunter, and the Chairman took part in the Discussion. The author replied by correspondence.

On the motion of the Chairman a vote of thanks was accorded to the author.

"THE RIVER CLYDE AND HARBOUR OF GLASGOW."

Paper by W. M. ALSTON.

Abstract.

THE RIVER.

THE river Clyde rises at about 2000 feet above sea level on the southern confines of Lanarkshire, and in its course of 102 miles to Port Glasgow drains about 1400 square miles of country. Anxious to secure improved communication with the sea, the magistrates of Glasgow in 1755 consulted John Smeaton, who found the river obstructed by shoals with from 15 to 24 inches depth at low water. His recommendation to canalise a portion of the stream was fortunately discarded, and, under advice by John Golborne in 1768, contraction by jetties was adopted.

Systematic improvement of the navigation commenced in 1773 by the removal of Dumbuck Ford, the most seaward obstruction. The deepening of the river was authorised as follows:—

In 1770—From Glasgow to Dumbuck Ford, to give 7 feet at high water, neap tides.

In 1809—From Glasgow to Dumbarton Castle, to give 9 feet at high water, neap tides.

In 1825—From Glasgow to Port Glasgow, to give 13 feet at high water, neap tides.

In 1840—From Glasgow to Port Glasgow, to give 17 feet at high water, neap tides.

By the inauguration of steam navigation in 1812, and the introduction of steam-worked dredgers in 1824, a great impetus was given to further improvement. Dredged materials generally were deposited on land, but since the introduction of steam hopper barges in 1862, almost all material has been carried to sea. The dredging plant now consists of five dredging machines, one floating grab, twenty steam hopper barges, a tug, many punts, and two diving bells. Between 1844 and 1900, 56,591,093 cubic yards have been dredged from river and docks. The general result is that the bed of the river from Glasgow to Dumbuck Ford has been lowered about 27 feet since 1755, and the bed has been made practically level from Glasgow to Port Glasgow.

Dredging is now being carried to a depth of 22½ feet below average low water, corresponding with about 33 feet at high water, with bottom widths ranging from 120 to 500 feet.

The progressive deepening of the river is indicated by the increasing draught of vessels, thus:—

	1821.	1831.	1841.	1851.	1861.	1871.	1881.	1891.	1900.
Greatest draught of vessel in feet ...	13½	14	17	18	19	21	22	23	26½

From the Kelvin to Erskine Ferry the river has now the artificial appearance of a canal, the sides consisting of rough stone slopes rising to three feet above high water, and the width varying from 365 to 560 feet. Seaward of Erskine Ferry the river widens in estuary form to two miles breadth at Port Glasgow. The only remaining training dyke is in the waterway between Dunglass Castle and Dumbarton Castle. Safe navigation is insured by numerous fixed and floating lights, all burning Pintsch's compressed gas, and ordinary buoys and beacons.

With regard to the tidal phenomena of the river, in 1755 springs rose only 1 foot 9 inches at Glasgow, and neaps were just sensible. Springs now rise 11 feet 4 inches, and neaps about 9 feet. The low water line has been lowered about 9 feet 7 inches. In 1768 high water was two hours later at Glasgow than at Port Glasgow, and now the interval is reduced to about one hour

For many years there was a weir above the harbour at Glasgow, but about twenty years ago it was removed. It is now, however, in course of being replaced.

GLASGOW HARBOUR.

Glasgow Harbour embraces the 2½ miles of river between Albert Bridge and the river Kelvin, and the docks on either side. The first quay at Glasgow was built about 1662, but by 1792 there was a length of only 262 yards, at which time 120 yards were added, bringing the total to 382 yards in the latter year, with a water area of 4 acres. For many years riverside quays sufficed for all accommodation. The first dock—Kingston Dock—was authorised in 1840, but not carried out until 1867. Powers were obtained in 1870 for Queen's Dock, and in 1883 for Prince's Dock; in 1890 the form of the latter was modified. The latest dock is that at Clydebank, about six miles below Glasgow, authorised in 1899, and now in course of construction. Although called docks, these works are tidal basins.

For brevity the harbour and dock accommodation is tabulated thus:—

	Length of Quays. Lineal yards.	Water Area. Acres.
Glasgow Harbour	6786	131.75
Kingston Dock	830	5.33
Queen's Dock	3334	33.75
Prince's Dock	3737	35.00
Govan Passenger Wharf	46⅔	—
Shieldhall Timber Yard Wharf ...	381⅓	—
Totals	15,115	205.83

The graving dock accommodation is as follows:—

	No. 1 Dock. 1875.		No. 2 Dock. 1886.		No. 3 Dock. 1898.	
	ft.	in.	ft.	in.	ft.	in.
Length of floor inside face of caisson	551	0	575	0	880	0
Width of entrance	72	0	67	0	83	0
Depth on sill at high water, average springs	22	10	22	10	26	0

NOTE.—No. 3 Dock is divisable by gates into lengths of 460 and 420 feet.

Fortunately for Glasgow, its trade is most varied: 2686 yards of quays are devoted to coal and ore, 669 yards to timber, 175 yards to cattle, 7459 yards to liners, 630 yards for fitting out, and the remaining 3496 yards to general traders. Where required the quays are lined with commodious sheds, of one storey, except at Prince's Dock, where most of them are two storied. There are no warehouses.

Numerous cranes, ranging in power from 35 cwts. to 130 tons, are provided. Water mains are laid throughout the harbour and docks, and the quays are lighted by gas and electricity. The quays are connected with the railway systems of the country. For cross river traffic there are four ferries for passengers and two for passengers and vehicles combined; while for up and down harbour traffic there is a fleet of small steamers called "Cluthas." Space does not permit of any description of the quay walls.

The improvement of the river and growth of the city have gone forward together. When the citizens entered on the task, they numbered only about 40,000, and the revenue from the navigation was only £147; now they number 760,406, and the revenue last year was £441,419. In 1792 the accommodation consisted of only 2½ acres of water and 262 yards of quay; now there are 206 acres of water and 15,115 yards of quay. Since 1810, when the management of the river and harbour was placed under trustees, down to June, 1900, the capital expenditure has been £7,430,702.

In conclusion, the river Clyde is a magnificent example of what can be done by a public body, without any assistance from Government.

The following members took part in the Discussion:—Mr. R. C. H. Davidson, Mr. William Brodie, Mr. Alexander Gibb, Mr. H. Home, Mr. W. H. Hunter, Mr. James Brand, Mr. R. Gordon Nicol, Prof. Vernon-Harcourt, and the Chairman. The author then replied to their remarks.

On the motion of the Chairman a vote of thanks was accorded to the author.

The meeting was then adjourned.

THURSDAY, 5th SEPTEMBER, 1901.

Sir JOHN WOLFE BARRY, K.C.B., LL.D., F.R.S., in the Chair.

"IMPROVEMENT WORKS ON THE CLYDE ESTUARY."

Paper by D. and C. STEVENSON.

Abstract.

THE lower estuary of the Clyde, which may be called the key to the upper navigation, and with which this paper deals, is under the jurisdiction of the Clyde Lighthouses Trustees, the jurisdiction of the Clyde Navigation Trust ending above Port Glasgow. The estuary extends from Port Glasgow westwards, the channelway passing through sandbanks until the "tail of the bank" is reached, below which the estuary is more of the nature of a firth or fiord, the depth of water varying from 180 feet at Cloch to 370 at the Cumbrae, although it is deeper at some places, such as opposite the Cloch, than at places more seaward, such as Skelmorlie. It is encumbered by several "patches," the highest up being that of Roseneath, with a depth of 7 feet over it at low water, situated midway between Fort Matilda and the Roseneath shore. The depth of the estuary here varies from 60 to 220 feet; and the slope of the bottom from the tail of the bank is no less than 190 feet in one mile. The Gareloch, one of the numerous arms of the Clyde estuary, branches off here; and a little lower down, where the estuary takes a right-angled bend to the south, Loch Long comes in. It is navigable for large ships to its head, which forms the starting point of the projected great Scottish Canal connecting the Clyde and the Forth by Loch Lomond, which, being only 10 feet above high water, necessitates little lockage, and has an almost inexhaustible supply of water. From Loch Long the Clyde estuary is practically the sea with but few dangers. The Gantock, lying off Dunoon, is guarded by a gas-lighted beacon; then another obstruction, called the Warden Bank, is met with, which, till recently, was not shown on the Admiralty charts, and was not generally known to exist. It forms an extension of Lunderston Bank, and has 34 feet of water over it at dead low water, so that it does not form a danger to ordinary traffic of the present draught.

Within a few yards of this rocky ledge there is a depth of no less than 300 feet, so that the west side of the Warden Bank is a submarine precipice. Skelmorlie Patch is the next shoal, the boulders coming to within a few feet of the surface. It forms a danger at present guarded by a gas-lighted buoy and bell. The estuary south of this to the Little Cumbrae is from 30 to 60 fathoms in depth, and the navigation through it is unimpeded by dangerous shoals.

The Clyde, it will be seen, differs from most of the navigable rivers of this country in that it does not flow direct into the sea with the natural accompaniment of a bar, but enters into a deep and sheltered estuary. The estuary itself is encumbered with sandbanks, but owing to their sheltered situation they are not stirred up to any great extent by heavy waves, and the sand is not carried in to choke up the channelway. There is no "fretting" of the banks, as in the Mersey, for example. The Clyde Lighthouse Trust, which succeeded the Cumbrae Trust in 1871, immediately took steps to carry out the powers which Parliament had delegated to them, and appointed Messrs. Stevenson, of Edinburgh, their engineers. The improvement of the estuary between Port Glasgow and the tail of the bank involved, at the same time as the improvement of the estuary to Glasgow, the conservation of the entrances to the harbours of Port Glasgow and Greenock. These harbours required to have the benefits of a navigable fairway in close proximity, and yet the channelway for the ordinary river traffic had to be sufficiently removed from the shore that ships passing to other ports might be comparatively free from interruption due to the local traffic to Port Glasgow and Greenock. The inconvenient curves round Garvel Point, and the bight at Cartsdyke, also required to be dealt with and made easier for the passage of large ships. A channelway, or rather what is really a ship-canal, has now been formed from Newark Castle (Port Glasgow) to Prince's Pier, Greenock, having nowhere a less depth than 23 feet at low water of spring tides, with a minimum width at the bottom of 300 feet, and slopes of 100 feet on either side, having depths varying from 20 to 23 feet. Before this canal was begun the ruling depth at that part of the estuary was 12 feet. The curves at Garvel and Cartsdyke have been eased by fully one half. These improvements, great though they are, cannot be taken as final, as the draught of ships is still on the increase, and perhaps at no very distant date further deepening and widening of this channelway may be called for by the shipping interest. This deep-water channel has been marked on its northern side by buoys and a lightship lighted by gas, while the southern side has also been similarly marked by buoys, and gas-lighted beacons and buoys. Pilots can, therefore, take vessels through the estuary at night almost as well as by day; and when fog obscures the lights, the fog signals at Kempock Point, Fort Matilda, Cloch, Toward, and Cumbrae give their warning note to the sailor that he is near them.

The removal of wrecks becomes sometimes a serious matter in such navigations. In the case of the "Auchmountain," lying as it did in good anchorage ground, the wreck had to be repeatedly tackled with explosives, and finally, on the suggestion of our firm, was covered up by dredgings, which has made the anchorage a perfectly safe one.

The tidal flow has been greatly facilitated by the dredging works, causing the tidal flow at Port Glasgow (where the Clyde Lighthouses Trustees' works described were executed) down to Greenock to be more distinctly that of the sea proper than it was; and especially is this an improvement from a sanitary point of view, as it renders the admission of fresh water more rapid, although the actual gain is not so much as might be wished, owing to the counter effects of the greater amount of sewage to be dealt with than in former days.

The Chairman, Mr. W. H. Hunter, and Prof. Vernon-Harcourt took part in the Discussion; and Mr. C. A. Stevenson replied.

On the motion of the Chairman a vote of thanks was accorded to the authors.

"WORKS FOR IMPROVING THE BILBAO RIVER AND MAKING AN OUTER HARBOUR: ALSO, THE APPLICATION OF LARGE CAISSONS AS A BREAK-WATER FOUNDATION."

Paper by EVARISTO DE CHARRUCA.

Abstract.

THE maritime part of the Nervion River, which forms the port of Bilbao, has a total length of 8⅔ miles, the town being situated in the upper part. This river has a torrential character, and has little influence on the navigable depth, which is kept up exclusively by the tidal waters.

The oldest documents show that this river had a shifting and shallow bar, and the river itself had sharp curves and many obstructions, all of which existed to within a few years ago, despite all the training walls built in past centuries.

The Bilbao Chamber of Commerce, thinking that such conditions should not continue, obtained from the Government, in 1877, leave to create a Harbour Improvement Board, with power to levy certain dues on imports and exports, for defraying the cost of the works of improvement.

Most excellent results were obtained at the bar by building out a training jetty 800 metres (2625 feet) in length from the left bank of the river mouth. Formerly only two feet depth existed at low tides on the bar; whereas, after building the jetty, a permanent channel along its whole length was maintained, with a minimum depth of 13 feet at low water of spring tides. This enabled steamers drawing 22 to 24 feet to go in and out at spring tides, and 18 to 20 feet at neap tides; whereas, before the works were executed, the maximum draught of steamers was 14 feet at spring tides and 10 feet at neap tides.

The works executed in the river itself did away with all the obstructions, and obtained over 14 feet depth at low water of spring tides up to Bilbao. But as the river mouth is directly exposed to north-westerly gales, the entrance of steamers continued to be dangerous during bad weather, a defect that could only be removed by the construction of sheltering breakwaters; and as in doing this it was possible, at the same time, to create a large outer

harbour for the use of steamers at all states of the tide, the following plan was adopted.

This outer harbour is enclosed by two breakwaters—(1) The west breakwater, 1450 metres (4757 feet) long, running out from the coast at right angles to the north-west; (2) the eastern breakwater, running out in a westerly direction, is 1100 metres (3610 feet) long. Between them there is an entrance 600 metres (1970 feet) wide, facing the north-east. The area protected by the two breakwaters is 741 acres, with a maximum depth of 46 feet at low water of spring tides. The first breakwater is the more important of the two, and rests on a bottom of mud and sand, except near the coast, where the rock is uncovered.

As there were few days in the year during which it would be possible to work with divers, it was decided to build the superstructure from the level of low water, and to let it rest on a large mound of concrete blocks, of 30 to 50 cubic metres (39¼ to 65½ cubic yards), which in turn would rest on a large mound of sorted rubble. The building of the superstructure was begun in 1891, and was damaged in 1893 and 1894, when the superstructure built on the concrete blocks and rubble mound had a length of 127 metres (417 feet).

As it would have been very hazardous to persevere in building the superstructure on the foundation of loose blocks already laid, the solution that appeared the wisest to adopt was to leave all that part as an outer protection, and to build the superstructure further back under its shelter.

It was decided to build the superstructure upon large steel caissons filled with concrete, and resting 5 metres (16 feet 5 inches) below low water—a system that was accepted by the Government in 1895. The caissons are 13 metres by 7 metres by 7 metres—637 cubic metres (833 cubic yards)—so that when placed at a depth of 5 metres below low water of equinoctial spring tides, they would emerge 2 metres (6½ feet), as it was necessary that the top of the caissons should be above the water-level at every low tide, to enable the work to be carried on inside. As it was necessary to fill these caissons rapidly, so that the sea might not break them, we decided to ballast them with a layer of concrete 1.50 metre (5 ft.) thick before they were floated out to their place, and afterwards to deposit inside them, by means of a Titan, 12 blocks of 30 cubic metres (39¼ cubic yards) each. At the next low tide, the water is pumped out from between the blocks, and concrete run into the interstices, and lastly a layer an the top of them 0.50 metre (1⅝ feet) thick, so as to make one monolithic block of 637 cubic metres (833 cubic yards).

The superstructure is built upon this foundation, formed by two face walls made with concrete blocks of 30 cubic metres (39¼ cubic yards) each, and a hearting of rapidly setting concrete. This brings the work up to 7 metres (23 feet) above low tide, and it is protected on the sea side by a strong parapet.

The system of construction explained has, in addition, the very great advantage of allowing the superstructure to be built in separate lengths of 7 metres (23 feet), so that they can settle quite independently on the mound.

Up to 31st December last 150 caissons had been placed in five and a half years, without the slightest mishap; and the system can safely be adopted for seas as violent as those of the Bay of Biscay.

After two winters have elapsed it is considered that the caissons have settled down to their full extent, and the joints between them, and between the superstructure sections built upon them, which are about 12 inches wide, are filled with concrete; and the parapet wall is subsequently built.

The construction of the east breakwater calls for no special remarks, because the sea waves run nearly parallel to it. It is built on a foundation of concrete bags, which, in their turn, rest on a rubble mound protected by large concrete blocks.

The Discussion was combined with the Discussion on the Zeebrugge Harbour Works (see p. 84). The author replied.

On the motion of the Chairman a vote of thanks was accorded to the author.

"ZEEBRUGGE HARBOUR WORKS."

Paper by J. NYSSENS HART and L. VAN GANSBERGHE.

Abstract.

THE port of call of Zeebrugge is formed by a curved breakwater extending out to sea, and consisting of a sea wall and harbour wall, with filling between, forming a quay. It is also provided with an entrance channel and lock, which connect the roadstead, sheltered by the breakwater, with an inner basin in communication with the Bruges ship-canal. The breakwater consists of three portions. The first portion on the beach is a solid embankment; the second portion, which is a continuation of the first, is an open-work viaduct 400 metres (1312 feet) long; the third portion is a solid breakwater and quay, 1605 metres (5264 feet) long. The third or solid portion of the breakwater comprises two parts. The first part consists of a quay with a sea wall on the outside, which protects the filling between the sea wall and the harbour wall, forming the quay; and alongside the quay or harbour wall, 1271.40 metres (4170 feet) long, there is a general depth of 8 metres (26.24 feet) at low water of spring tides, for a width of 300 metres (984 feet). The second part is a straight length of solid sea wall, 340 metres (1115 feet) long, which constitutes an outer breakwater.

The base of the sea wall protecting the quay of the third or solid portion of the breakwater, consists of monolithic concrete blocks weighing 3000 tons; these are 25 metres (82 feet) long, by 7.5 metres (24.6 feet) wide, and their height varies according to the depth of the sea, so that the top of all the blocks may be 1 metre (3.28 feet) above low-water level.

The straight length of sea wall constituting the outer breakwater beyond the quay is larger, the foundation blocks being 9 metres (29.52 feet) wide. The main body of the sea wall consists of 55-ton blocks laid upon the foundation blocks, up to a level of 7 metres (22.96 feet) above low water of spring tides. Upon these is built a sheltering wall 4.80 metres (15.74 feet) high, and a parapet 1.20 metres (3.94 feet) high; the summit of the latter being thus 13 metres (42.64 feet) above low water. The toe of the sea face of the breakwater is protected from undermining by a mound of large blocks of rubble stone, weighing from 300 to 2000 kilogrammes (5.9 cwt. to 39.36 cwt.).

The quay wall which protects the embanked portion of the breakwater on the harbour side is built on foundation blocks

25 metres (82 feet) long, laid on the sea bottom, which has been previously dredged to a level of 8 metres (26.24 feet) below low water, for a length of 876.41 metres (2876.6 feet), and to a level of 9.5 metres (37.16 feet) below low water for a length of 393 metres (1289 feet). These blocks are 9 metres (29.52 feet) wide at the base, and 6m.20 (20.34 feet) wide at the top. Upon these are laid the courses of 55-ton concrete blocks, up to a level of 7.30 metres (23.94 feet) above low water.

The space between the sea wall of the breakwater and the quay or harbour wall is filled in with earth, and covered with stone pitching. This quay space carries the sheds, buildings, lines of railways, cranes, etc.

The foundation blocks are built of concrete in iron caissons, which remain part of the blocks. These concrete blocks have large cavities in the first instance, providing sufficient displacement, in comparison with their weight, to enable them to be towed out floating into position, without danger of sinking during the voyage; and they are then sunk and filled up with concrete. These blocks are made in the basin forming the inner harbour, just above the sea lock. Four sizes of blocks are employed. Those used for the outer solid breakwater beyond the quay are 25 metres (82 feet) long, 9 metres (29.52 feet) wide, and 8.75 metres (28.72 feet) high, which represents a cubic capacity of nearly 2000 cubic metres (2616 cubic yards), and a weight of about 4400 tons. The lower part of the caissons has a cutting edge to enable it to penetrate into the ground, which consists of clayey sand. When the sea bottom upon which the block is to be founded is uneven, it is levelled by means of rubble deposited by hopper barges. Orifices are provided in the shell of the hollow block for letting in the water to sink it. When the block has been deposited upon its foundation, it is filled with concrete by means of skips of 10 cubic metres (13.08 cubic yards) capacity, which open at the bottom directly they begin to be drawn up.

Up to the present time, four caissons have already been deposited; these form the starting point on the sea side of the solid portion of the breakwater.

The Discussion was combined with that on the preceding paper.

The following members took part in the Discussion:—Prof. Vernon-Harcourt, Mr. P. A. Fraser, the Chairman, Mr. J. R. Baterden, M. Mendes Guerreiro, Mr. de Charruca, and Mr. W. H. Hunter; and M. Van Gansberghe replied.

On the motion of the Chairman a vote of thanks was accorded to the authors.

"RECENT IMPROVEMENTS IN THE LIGHTING AND BUOYING, Etc., OF THE SCOTTISH AND ISLE OF MAN COASTS."

Paper by David A. Stevenson.

Abstract.

A glance at a chart of Scotland shows that, owing to its exceptionally rugged coast-line, and numerous outlying islands and dangers, the task of lighting and otherwise guarding it effectually for the purposes of navigation, is an interesting and difficult problem for the lighthouse engineer.

Owing to the want of funds, little was done up till 1854 to light the Sounds and Kyles on the West Coast, between the outlying islands and the mainland, and the coasts of the Orkney and Shetland Islands, and of the Western and Northern shores of the mainland. The war of 1854, however, made it necessary that something should be done to enable the fleet to navigate the Northern seas at least with some degree of safety, and the advantage of lighting the West Coast sounds came also about the same time to be appreciated. Since that period good progress has been made, and in 1875 there were 60 lighthouses, 98 buoys, 49 beacons, and 2 fog signals on the coast. Druing the last twenty-five years (since 1875) there have been erected on the coasts under the jurisdiction of the Commissioners of Northern Lighthouses, 16 lighthouses, 21 fog signals, and 28 lighted beacons; and there have been laid down 1 lightship, equipped with a fog-signal, 15 lighted buoys and 9 unlighted buoys, and 1[illegible] unlighted beacons have been erected.

The course of a seaman making for and navigating the Scottish coast has thus been much facilitated, though no doubt much remains to be done, for there are still many outlying dangers unguarded, and stretches of coast line with 50 or even 100 miles between the lights, while the range of our most powerful lights in weather when they are most required does not exceed 9 or 10 miles.

The characteristics of the lights on the Scottish coast have also been much improved as regards their distinctive character, which, next to the existence of a light at all, is the most important factor in its usefulness. It has been the policy of the Northern Lighthouse Board to gradually alter the old fixed lights which are liable to be mistaken, or, at all events, not so readily recognised and identified, and give them a definite character. During the last twenty-five years eight fixed lights on the coast of Scotland have been altered to flashing or occulting lights. The introduction by Messrs. Chance in 1874 of the group-flashing characteristic, pro-

posed by the late Dr. Hopkinson, put into the hands of the lighthouse engineer the power of greatly varying the character of lights, and many lights of this character have been installed on the coast. Further, the periods of many of the lights have been shortened as much as possible, consistently with other considerations. Not only has the *number* of the lights been increased and the *characters* improved, but the *powers* of the lights on the Scottish coast have been greatly increased. Thus, in 1875 the most powerful light on the Scottish coast had a power equal to 44,500 candles; now there are several over 100,000 candles, and the Isle of May electric light has a power which is calculated is equal to 3,000,000 candles. The limitation of the duration of flashes to about half a second, and the reduction to a minimum of the number of faces of the apparatus have long been recognised as leading principles, and acted on in Scotland where consistent with producing the proper characteristic, and a duration of flash of sufficient length. The recent increase in the power of the apparatus has been effected by the use of one or both of the following improvements in lighthouse apparatus, which have been described by Messrs. Chance as "most valuable improvements."

(1) The introduction of hyper-radiant or long focal distance apparatus proposed by Messrs. Stevenson in 1869, designed and experimented on by them in 1885, and introduced in many lights since that date both at home and abroad. (2) The introduction of Mr. Charles A. Stevenson's equiangular prisms, which effect a saving of 15 per cent. of the light incident on them at 45 deg., and 26 per cent. at 40 deg., and which permit with efficiency of the use of refractors of 80 deg. focal opening in place of only 60 deg. with Fresnel elements. The adoption of flint glass to extend the refracting portion to 80 deg. caused more loss of light than if catadioptric prisms had been used for this portion; indeed, the great divergence from the prisms, and the loss of light due to using flint glass, rendered this portion of the apparatus practically useless as a lighthouse agent.

This increase in the power of the lights has not been effected by increasing the size of the burners employed, as no burner of a larger diameter than six wicks for hyper-radiant, and five wicks for first-order flashing lights has been introduced, because, owing to want of focal compactness, and the fact that little increase of intensity is obtained, larger burners are considered not to warrant the additional consumption in oil and difficulty of management they entail. Nor has the length of flashes been reduced below four-tenths of a second, as anything less than about half a second is considered too short to give, under practical conditions, full perception.

With the exception of one electric light and five stations where oil gas is employed, four of which are also incandescent, the illuminant used in the Scottish lighthouses is paraffin. The introduction of gas as the illuminant has permitted, at less important stations, of dispensing with the attendance of one of the keepers, reducing the staff to one, who is rung up should anything go wrong with the light by an electric automatic alarum.

In the case of lights made by oversea vessels, and coast lights which are intended to light long stretches of coast, it is necessary that they should be of considerable power, and that they should be constantly attended by keepers to ensure their due exhibition. There are, however, many places on the Scottish coast, as in sounds, lochs, and firths, where lights do not require to be seen at a great distance, and where even the extinction of the light for a time would only cause inconvenience to the sailor, not disaster. In such cases the lights may obviously be of low power, and be unattended continuously by keepers. Lighted beacons and buoys have consequently been introduced at such places on the Scottish coast, to the great advantage of navigation, and at a very small cost. Twenty-three of these beacons and buoys are lighted on Pintsch's system of compressed oil gas, and have given complete satisfaction. They require only to be visited once in six weeks or so.

Originally the fixed-light character was all that was available, but, on Messrs. Stevenson's suggestion, Messrs. Pintsch introduced a method whereby they show one, two, or three flashes as desired, and this has greatly increased their usefulness besides reducing the consumption of gas. Twenty-one beacons are lighted with petroleum burned in the Benson-Lee and Lee lamps, in which the wicks are carbon-tipped, and require attention every four or five days, but are an improvement, as regards safety and power, on the Norwegian Trotter-Lindberg system which was first used in this way. When these lights require to be made flashing, this is produced by revolving shades driven by the current of heated air from the flame.

The buoys in use on the Scottish coast have been increased in size and improved in shape, so as to ride upright even in strong tidal currents, and they are for these reasons more easily seen and picked up by the sailor.

The Otter Rock light-vessel just launched will be unattended by a crew, and has been designed to lie in a very exposed situation. The lantern apparatus and glass-work were specially designed to suit the circumstances, and made by Messrs. Chance. The gas fittings are on Messrs. Pintsch's system, and they are the contractors for the work.

Owing to the prevalence of fog and snow showers on the Scottish coast, amounting to between 300 and 400 hours in the year, and lasting occasionally for spells, without a break, of 36 hours, the question of fog signalling is very important. Fog signals minister not only to the safety of navigation, but facilitate the making of regular passages, and hence are greatly appreciated by the sailor and the shipowner. The 24 fog signals erected on the Scottish coast during the last 25 years have explosive cartridges at two stations, and siren fog-horns actuated by compressed air at all the rest. These tonite signals, which give a loud report, were originated by the Elder Brethren of the Trinity House, and are of great value in certain situations. They are only used on the Scottish coast at rock stations, where the siren horn could not be introduced except at a very large cost, as they are not so efficient and much more expensive to maintain than fog-horn signals. For fog-horns the motive power to compress the air used 25 years ago was hot-air engines, which were excellent for the purpose, as they did not require a supply of fresh water, which is not easily obtained at most lighthouse stations; but, on the other hand, they took about three-quarters of an hour to start, and were costly to keep in repair. Messrs. Stevenson accordingly introduced in 1883 gas-engines driven by oil gas. They require little water, and have not the drawbacks of the hot-air engine; and his having proved successful, they followed it up by the introduction in 1889 of the oil engine, then just perfected. Both of these improvements were first used for fog signalling purposes in Scotland, and the oil engine is now almost invariably so used. Steam engines have been introduced at two stations, in one case because steam boilers were already at the station for the electric light engine, and in the other because the oil engine had not been introduced, and, being a lightship station, the choice lay between hot-air and steam engines.

Where oil engines are used, a fog-horn can now be put in operation in about eight minutes, even if there is no air stored, which, however, is done in several cases, so that the signal can be practically instantaneously started. In recent cases the engine power introduced at fog-signal stations has been about 50 H.P., one-third of which is reserve. The working pressure used, as a rule, is about 30 lbs. per square inch, and about 46 cubic feet of air per second of blowing is expended. The siren used is a modification of Mr. Slight's cylindrical siren. By improving the shape and enlarging the horn and air passages, opening out and properly forming the air ports of the siren, driving the siren by an air motor, and properly proportioning the storage to the air consumption, Messrs. Stevenson have recently greatly increased the efficiency of the siren fog-horn.

For the purposes of distinction, groups of blasts have been introduced, two, three, and four blasts given in quick succession, and these are still further differentiated by making the blasts of different pitch when necessary. Their endeavour has been to make these blasts as long in duration as possible, consistently with due economy, their view and experience being that a long blast is more effective than a short blast, and that no blast should be less than three seconds, and that five seconds is what should be aimed at. The periods of some recent signals have also been reduced to 1½ minute, though this is, in their opinion, perhaps unnecessarily short, as in most situations a two or even three minutes' period would serve the sailor's requirements, permit of a great reduction of the power, and therefore reduce the expense necessary to produce an effective signal.

In spite of all that has been done to improve our fog-signals, they are undoubtedly the weak point in the provision made for leading and guiding the sailor. This is, it is to be feared, inherent in the system of using the air as the carrier of fog-signal warnings, for sound signals are uncertain both as to penetration and location, and the solution of the difficulty will probably ultimately be found in Mr. Charles A. Stevenson's proposal of 1892, of an electric cable or conductor laid down off a coast or danger so as to act on an instrument on board each vessel, and thus either warn the sailor of his proximity to it, and therefore to a coast or danger, or act as a lead along which vessels might sail, keeping, as it were, in touch with the cable.

Although not directly connected with the guarding of the coast, the remoteness of many of the lighthouses on the Scottish coast —one of which is 40 miles from land, one 20, and several about 12 —at a very early period caused consideration to be given to the possibility of connecting them with the shore by electric telegraph. The expense involved prohibited the adoption of electric cables; and in 1894 the Commissioners of Northern Lighthouses made an experiment of the wireless system of telegraphy proposed by Mr. Charles A. Stevenson, on the scale and distance that was required for one of the stations in the Northern Lighthouse Service. This experiment, which was carried out with the assistance of the General Post Office officials in Edinburgh, proved quite successful; but the Board of Trade declined to sanction its adoption on the ground that flag signals were sufficient. Since then many other similar or cognate proposals have been suggested, but nothing practical has yet been done.

The Discussion was combined with that on the papers by Baron Quinette de Rochemont, Mr. Harding, and Mr. Brebner (see p. 97). The author replied by correspondence.

On the motion of the Chairman a vote of thanks was accorded to the author.

"RECENT IMPROVEMENTS IN THE LIGHTING AND BUOYING OF THE COASTS OF FRANCE."

Paper by Baron QUINETTE DE ROCHEMONT.

Abstract.

THE Department of Lighthouses and Beacons in France, under the able direction of the late and regretted M. Bourdelles, has introduced many improvements in the lighting and buoying of coasts.

The illuminating power of lighthouses has been greatly increased by:—

1. Increasing the intrinsic brightness of the luminous source.
2. Greater perfection in the manufacture of the optical apparatus.
3. Reducing the number of lenticular panels, and increasing their surface and power by employing lightning lights.

The brightness of the beam from a lenticular panel is proportionate to the intrinsic brightness of the luminous source at the burner, and not to the luminous intensity. The mean intrinsic brightness of flames, produced by oil lamps, increases only to a slight extent with the size of the flames. The illuminating power of lighthouses can, therefore, only be improved to a slight extent by increasing the number of wicks. The adoption of Auer incandescent burners, for compressed gas and petroleum vapour, has enabled a great practical improvement to be effected. Incandescent lighting by acetylene gas will probably give still better results, at any rate, as regards light efficiency. The intrinsic brightness of various systems of lighting employed in lighthouses is as follows, expressed in carcels(*) per square centimetre of the mean horizontal focal plane of the luminous source. It varies from 0.35 to 1.18 carcel for burners with mineral oil, employing from one to six wicks; and for incandescent lighting with compressed oil gas, petroleum vapour, and acetylene, it attains 2, 2.5, and 4 carcels, respectively. The crater of an electric arc has an intrinsic brightness of 900 carcels.

The luminous efficiency of the optical apparatus has been increased by improving the focal precision, and by keeping the characteristic or effective divergence within narrow limits.

With lightning lights, by reducing the duration of the flashes, as far as possible, to the time actually required for the full perception

---

* 1 carcel equals 9.5 candles.

of their luminous intensity, it has been possible to construct the optical apparatus with a small number of lenses of large surface, and consequently of great power.

The illuminating power has thus been raised to 50,000 and 60,000 carcels in lighthouses which have double sets of optical apparatus, such as at Ailly, where the illuminant is compressed gas; and at Vierge, where it is compressed petroleum vapour.

Although the increase of the intrinsic brightness of the luminous source exercises the principal influence in increasing the illuminating power of lighthouses, it is, nevertheless, necessary to consider to some extent the dimensions of that source.

Incandescent gas lighting, when no special gas works are required, is not much more expensive than lighting with a three-wick burner; and even when special works are necessary, it is more economical than a five-wick burner. The annual expenditure for gas lighting does not exceed 1800 francs (£72) with gas works, or 800 francs (£32) without works; for petroleum vapour lighting it amounts to 650 francs (£26).

The generating stations for recently-built electric lighthouses have been provided with the latest improvements; particular attention has been paid to the improvement of the alternators and the regulators.

The permanent lights have increased the safety of navigation by enabling the beacon towers and shoals out at sea to be illuminated, where the erection of ordinary lighthouses would have been precluded on account of the expense. These permanent lights employ wicks, the surface of which has been evenly coated with a thin layer of carbonised tar, the operation being termed "crontage," or caking. These permanent lights can have all the characteristics of superintended lights.

The consumption of oil is from 35 to 40 grammes (1.234 to 1.411 oz.) per hour. The illuminating power of these lights averages about 100 carcels for regular lightning lights, from 85 to 60 carcels for lights with groups of two or three flashes, and 8 carcels for fixed lights.

Other permanent lights, in the form of illuminated buoys, fed with oil gas, have been adopted on an extensive scale, especially to increase the protection at dangerous points, or as substitutes for lightships, and for lighting winding and shifting channels.

Considerable improvements have also been effected in the construction of lightships—

1. By eliminating synchronism between the period of oscillation of the lightship and that of the waves acting upon it.

2. By reducing the rolling due to the waves by the addition of side keels to the vessel.

The information afforded by the various trials and experiments carried out with the *Talais* and *Snouw* lightships has been utilised for the design of the lightship which is to be moored on the Sandettie. This vessel will be 35 metres (114 feet 10 inches) long, 6.24 metres (20 feet 5 inches) wide, with a depth of 5.10 metres (16 feet 8½ inches) from the deck to bottom of hold, at centre. It will have a displacement of 342 tons.

The illuminating portion will consist of a swinging optical apparatus for a lightning light, with an incandescent burner employing compressed oil gas as an illuminant. The illuminating power will be 3500 carcels.

The vessel will, in addition, be provided with plant for the sounding signal. This will comprise two boilers with distilling plant, self-condensers, and air-compressers; and a single siren worked by compressed air, with reservoirs and accessories.

It has been observed that the vibration and noise which occur in beacon towers are the effect of the impact of the waves. Considered from this point of view, in which the essential factor of resistance is the whole mass of the tower, it has been found advisable to build the latter in the form of a monolith.

Thus the most recent lighthouses at sea have been built with small stones set in Portland cement, with a facing of small pick-dressed stones. Similarly, beacon towers are constructed of concrete or of neat cement, deposited within framing. This simplified method of construction is economical and rapid, and, moreover, it increases the resistance of the work to the principal stresses to which it is subjected.

The Discussion was combined with that on the papers by Mr. D. A. Stevenson, Mr. Harding, and Mr. Brebner (see p. 97.)

On the motion of the Chairman a vote of thanks was accorded to the author.

"THE CHINESE LIGHTHOUSE SERVICE."

Paper by J. R. HARDING.

Abstract.

THE lighthouse service of China is a department of the Chinese Imperial Maritime Customs, which institution has, under the able administration of Sir Robert Hart, become practically the International Civil Service of the country, embracing within its comprehensive grasp many important undertakings other than the collection of revenue.

The paper is divided into the following seven sub-headings:—(1) Commencement of lighting the coast; (2) Description of the more important lights in chronological order; (3) The lighting of the Yangtze; (4) Fog signalling, oil storage, etc; (5) Staff; (6) Buoys and beacons; (7) Construction and maintenance.

1. When Sir Robert Hart first joined the Customs Service in 1859 the coast was practically unlighted, and the work of establishing suitable safeguards for shipping was only commenced in earnest in 1869, in which year Mr. D. Marr Henderson, M.Inst.C.E., was appointed engineer to the Lighthouse Department, where he remained until 1898.

The designs for most of the lights on the Chinese Coast were prepared by Mr. Henderson, and their erection was carried out under his directions.

2. A brief description is given of all the lights of any importance on the Chinese coast, and plans of the various stations accompanied the paper, with a chart showing the positions and characteristics of the lights. Among the most interesting stations are:—BREAKER POINT, about 30 miles south of Swatow. The tower, which is 120 feet in height to the lantern vane, was designed by Mr George Rendel, and consists of a wrought-iron cylinder or tube, made in sections and bolted together, containing a spiral stairway. The tube is enlarged at the top to a diameter of 12 feet, to form a service room and to carry the lantern, and it is stayed with eight large wrought iron stays, arranged in pairs, braced together, and secured to anchor-bolts embedded in Portland cement concrete. The tower was cheap, easily erected, and, what is of even more importance on the Chinese coast, easily transported and landed. The light is first-order dioptric white occulting, the occultations

being produced by an iron cylinder of slightly larger diameter than the burner, alternately raised and lowered by a suitable clockwork. SOUTH CAPE OF FORMOSA.—The interest attached to this station lies in the fact that it was built in a part of the island inhabited solely by savages, and had, in consequence, to be fortified. The lantern was protected by steel revolving screens, and on the gallery of the tower, which was of cast iron, a machine gun was fitted on racers. Round the base of the tower was built a wrought iron refuge or fort, communicating by bullet-proof passages with all the rooms in the keepers' dwelling-houses. Both fort and tower were fitted with suitable accommodation for the staff in case of siege, had water-tanks in the basement, and were supplied with a stock of provisions. The station was further protected by a loop-holed wall and a dry ditch, flanked by two small towers or caponnières, armed with 18-pounder cannon. PEI-YÜ-SHAN.—A fine hyper-radial light, floated on mercury, showing double flashes every half-minute.

A description is given also of a composite light-ship, 110 feet long by 25 feet beam, which has been recently built in Shanghai, and which shows a triple white flash, and is fitted with a powerful double-noted fog siren, operated by two 9½ horse power Hornsby-Ackroyd oil engines.

3. The Yangtze, which is probably the third largest river in the world, is navigable for deep-draught steamers up to Hankow, a distance of 620 miles; for light-draught steamers to Ichang, a further distance of 370 miles; and for special steamers as far as Chungking, another 400 miles, and perhaps even further.

The lighting is carried out with sixth-order lens lanterns, hoisted on suitable masts on shore, or on native craft fitted as light-boats, and attended to by native light-keepers.

Gas buoys on Pintsch's system are now being provided for use in the Yangtze, and it is hoped that some will be in position early next year.

4. Fog-signalling is undertaken mostly with cast-iron cannon, but four of the most important shore stations and three of the light-vessels are provided with sirens. A table is given, showing the average number of hours of fog during the year at various points on the coast.

The stations are supplied with water by large, underground cisterns, which are filled with rainwater from the roofs. This system of water-supply has been always found to be pure and sufficient.

The mineral oil used for the burners is not stored in bulk in tanks, but in its original tins and cases in specially isolated oil stores.

All the buildings in the Chinese light-houses are erected at some distance from the towers, in order that the latter may not suffer in case of a fire occurring in any of the quarters.

5. The more important coast lights are in charge of foreign keepers, whose pay ranges from about £18 to £9 a month. The river lights are manned by native keepers, whose monthly pay ranges from £3 15s. to 15s.

6. Whistling, bell, and ordinary buoys are in use, and a Wigham's buoy light has been experimented with. A considerable number of gas buoys' on Pintsch's system, are now under order, and should be watching early next year.

Portland cement concrete sinkers are now being used to moor the buoys with, and are found to be very economical. Buoys and beacons are all coloured on a uniform system.

7. The paper concludes with a description of the management of the service, at the head of which is Sir Robert Hart, Bart., G.C.M.G., the Inspector-General of Chinese Customs. The engineering is carried out by an engineer-in-chief, assistant engineer, and staff, and the hydrographical and surveying work is under the control of a coast inspector, the latter and the engineer-in-chief working in consultation regarding the selection of sites for lighthouses, etc.

There are at present 98 lighthouses, 4 light-vessels, 20 light-boats, 88 buoys, and 78 beacons under the management of the service, besides 17 lights on the coast in the hands of foreign nations.

The Discussion was combined with that of the papers by Mr. D. A. Stevenson, Baron Quinette de Rochemont, and Mr. Brebner (see p. 97).

The author replied, and on the motion of the Chairman a vote of thanks was accorded to him.

"IMPROVED RAPID GROUP-FLASHING LIGHTS."

Paper by ALAN BREBNER.

Abstract.

THE paper describes the combination of a complete subdivided eclipsing screen of two or more parts, with a revolving optical apparatus of two or more panels, by means of which group-flashing lights can be produced in greater power and compactness than by any other means. In this system a bivalve apparatus carries a screen of two sub-divisions, a trilateral apparatus one of three sub-divisions, and so on, each screen sub-division being attached to and revolving with its corresponding lenticular panel. One burner at the common focus of the lenses suffices for each complete apparatus. The principle of the French "lightning light" is absorbed by and perfected in this system. The trilateral form of optical apparatus is shown to possess advantages over any other form in respect of power and economy—a fact first brought to light by the author in 1890. Any one of the bivalve, trilateral, quadrilateral, or other polygonal arrangements of the optical apparatus, combined with the suitable eclipser, can give all the group-flash characteristics; whereas with the Hopkinson system or with the plain lightning-light system the number of panels must be at least 2, 3, 4, 5, or 6 for the 2ble., 3ple., 4ple., 5ple., or 6ple. group-flashes respectively.

No mirrors being required in the system described, opaque as well as transparent luminaries can be fully utilised.

An example of a quadruple-flash characteristic obtainable from a trilateral apparatus, making one revolution in 6 seconds, with a burner of reasonable and current dimensions, is as follows:—Flash, .1 sec.; eclipse, 1.9 sec.; flash .1 sec.; eclipse, 1.9 sec.; flash, .1 sec.; eclipse, 1.9 sec.; flash, .1 sec.; eclipse, 5.9 sec.—the total period being 12 seconds.

Although the paper does not dwell on this fact, the system makes it possible to produce such rapidly-delivered characteristics as the following, if the persistence of luminous impressions be taken into account:—Flash, .25 sec.; eclipse, .25 sec.; flash, .25 sec.; eclipse, .25 sec.; flash, .25 sec.; eclipse, .25 sec.; flash, .25 sec.; eclipse, .75 sec.; the total quadruple-flash period being only 2½ sec. Similarly the double and triple group-flashes could be given in 1½ and 2 seconds, and so on.

The paper is illustrated by a sheet of drawings, and a drawing and model of an optical apparatus, complete with eclipsing mechanism, were shown at the meeting.

A combined Discussion was held on the papers by Mr. D. A. Stevenson, Baron Quinette de Rochemont, Mr. Harding, and Mr. Brebner, and was taken part in by the following members:—M. Ribiere, Mr. J. R. Harding, Mr. C. A. Stevenson, the Chairman, and Mr. N. G. Gedge. The author replied by correspondence.

On the motion of the Chairman a vote of thanks was accorded to the author.

On the motion of the Chairman a vote of thanks was accorded to the Honorary Secretary, Prof. Vernon-Harcourt, and on the motion of Baron de Rochemont a vote of thanks was accorded to the Chairman, Sir John Wolfe Barry, and to the Committees of the Congress. The Chairman briefly replied.

The proceedings then terminated, and the business of the Section was brought to a close.

SUMMARY OF PROCEEDINGS

OF

Section III.—Mechanical.*

TUESDAY, 3rd SEPTEMBER, 1901.

Mr. WILLIAM H. MAW in the Chair.

The Chairman opened the Proceedings with a few remarks.

"THE COOLING OF THE CYLINDERS OF HIGH-SPEED INTERNAL COMBUSTION ENGINES, AND ITS EFFECT UPON THE POWER DEVELOPED."

Paper by Professor H. HELE-SHAW, LL.D., F.R.S.

Abstract.

THE author commenced by giving his experience with the cooling of small internal-combustion engines for motor cars, and explained a method by which he had applied water cooling by gravitation to a voiturette with extremely satisfactory results. He mentioned that both with the voiturette in question and with a motor tricycle the water on a hot day during a long run is for considerable periods at a time on the boil without the power in any way appearing to diminish; whereas, on the other hand, he had been on larger cars where owing to the defective working of the pump, the water was not circulating properly, and a considerable amount of steam was being formed. In the latter cases the power fell off in a very serious manner; although the engines never actually stopped, as has been seen with air-cooled motors.

Amongst those who are accustomed to drive motor cars there is generally a feeling that the engines work best at a certain temperature, somewhere between that at which the water boils off and the cold state in which the engine actually starts. The author

* The full Proceedings of Section III., being Part IV., 1901, of the Proceedings of Mechanical Engineers, are published by the Institution of Mechanical Engineers, Storey's Gate, St. James's Park, Westminster, London, S.W. Price 4s. post free.

was not able to find that there existed any actual data upon this subject, and it seemed to be a sufficiently important matter to be worth making some experiments upon. He has, therefore, with the assistance of Mr. Gill, B.Sc., engineering student of the University College of Liverpool, experimented upon a 6 H.P. engine. This engine, which has magneto-electric ignition, was fitted with two thermometers, measuring the temperature of the water at entrance and at exit. A tank was used when the water was allowed to remain at boiling point; but otherwise the two pipes were connected with the mains, and the water at exit kept at the temperature required by allowing a sufficiently rapid flow of water through the cylinder-jacket. The power was accurately measured by means of a dynamometer brake acting on a flywheel. A series of five trials were made, four with the water at different temperatures, and a fifth with glycerine circulating in the cylinder-jacket and tank instead of water, in order to obtain a higher boiling point and a higher temperature of the cooling liquid.

The general result of these trials is given in the following table. The two series of boiling-off experiments have been kept separate from the other three; but the plotted results indicate the same general result:—

Summary of Tests.

Trial No.	Temperature at Entry.	Temperature at Exit.	B.H.P.	Revs.
	F.°	F.°		
1	66·2	77·0	4·775	1086
2	64·4	131·0	4·47	1084
3	64·4	212·0	3·97	903
4	212·0	212·0	4·07	925
5*	253·4	253·4	3·937	906

In experiments 1, 2, and 3, the water was running through.

In experiment 3 only a small quantity was allowed to flow, as it was completely evaporated.

Nos. 4 and 5 were boiling-off experiments.

* With Glycerine.

The general nature of these experiments is immediately obvious, and indicates a falling off in brake horse power as the temperature rises, the brake horse power between the two extremes of temperature having fallen from 4.775 to 3.93, a diminution of about 17 per cent.

Each series of experiments represents, roughly speaking, about ten observations, which were conducted as carefully as possible; but, at the same time, the difficulties of maintaining uniformly the temperature and speed of the engine were sufficiently great to make it undesirable to attempt to produce any mathematical statement from these results. Further and more elaborate experiments will be required, taking temperature in conjunction with the actual quantity of water used, before any definite conclusion can be arrived at on this subject. It is interesting to note that Mr. Dugald Clerk, in reply to a letter from the author asking for information, appears to have obtained, with a slow-running gas engine, slightly greater efficiency at the higher temperatures; but, of course, the foregoing experiments only deal with actual power, and not with efficiency.

The author has not attempted to discuss the actual cause or causes of the falling off in power as the temperature of the cylinder rises. Whether this is due to lubrication difficulties or thinning of the cylinder lubricant to a point which allows the piston rings to leak, or whether due to heating of incoming charge and consequent weakening of the mixture, would afford matter for an interesting discussion.

The advances in the construction of these high-speed internal-combustion engines, and the rapidly increasing power which is being evolved from them, warrant their careful study. Thus, in the recent Paris-Berlin race, there were several engines upon light motor vehicles, capable of developing more than 50 H.P., with in one case at least a weight of not more than 10 lbs. per horse power. When it is remembered that this is not merely the equivalent of the steam engine, but of the engine and boiler, it will no doubt be admitted that any point, such as the cooling of the cylinders, which is an essential feature of the problem, is worthy of the attention of the Congress.

The following members took part in the Discussion:—Mr. Bryan Donkin, Herr R. Diesel, Mr. Blackwood Murray, Mr. Dugald Clerk, and the Chairman.

The author replied, and on the motion of the Chairman a vote of thanks was accorded to him.

"TRIALS OF STEAM TURBINES FOR DRIVING DYNAMOS."

Paper by the HON. CHARLES A. PARSONS, F.R.S., and GEORGE GERALD STONEY.

Abstract.

THE earlier forms of steam turbines were described in a paper read before the Institution of Mechanical Engineers in 1888, but since that date great improvements have been made both in the design and construction—leading, especially in the case of large condensing turbines, to a very remarkable degree of economy.

Prior to 1890 all the steam turbines constructed were of the non-condensing type of small size, but in 1892 one of 100 kws. was constructed for condensing. With a steam pressure of 100 lbs. per square inch, and moderate superheat, a steam consumption of 27 lbs. per kw. hour was obtained by Professor J. A. Ewing, F.R.S., a result rivalling the performances of the best compound reciprocating condensing engines.

This result placed the steam turbine among the most economical means of obtaining electric energy from steam, and led to its adoption in the lighting stations of Cambridge, Scarborough, Newcastle, and other places.

About two years later considerable improvements were introduced, the single flow type of turbine being adopted, in which the steam passes parallel to the axis, with balancing pistons to take up the end pressure; these alterations both improved the economy and also decreased the amount of workmanship involved. At the same time the steam vanes or blades were strengthened and improved.

The following performances in condensing turbines with saturated steam of 140 lbs. per square inch pressure were recorded; a 24 kilowatt plant gave 28.8 lbs. per kw.; a 50 kw., 28 lbs. per kw.; a 100 kw., 26.4 lbs. per kw.; a 200 kw., 24.2 lbs. per kw.; and a 500 kw., 22.7 lbs. per kw. With a moderate superheat of 50 deg. F. these results are improved by about 8 per cent.; and with 100 deg. F., by about 12 per cent.

With two 1000 kw. turbo alternators for the City of Elberfield, with 140 lbs. steam pressure, and about 25 deg. F. of superheat, driving their own air pumps, the following remarkable results were obtained on the official trials:—

Load in kws..................	1250	1000	750	500	520
Lbs. steam per kw. hour	19.0	20.2	22.0	25.1	33.6

It should be pointed out that, as there is no internal lubrication in the steam turbine, there are none of the usual difficulties attending the use of superheated steam, and also that the water from the hot-well is absolutely free from oil, and therefore can be used direct in the boilers.

As might be expected, non-condensing turbines do not give such high results, but with about 130 lbs. steam pressure 39 lbs. per kw. has been obtained in a 100 kw. plant, and 38 lbs. in a 250 kw. plant, without superheat.

In larger sizes of, say, 1500 kw., with 200 lbs. steam pressure and 150 deg. F. superheat, a consumption of 28½ lbs. per kw. non-condensing has been guaranteed, and is expected to be easily obtained, if not surpassed.

The following members took part in the Discussion:—the Chairman, Professor Schröter, Professor William Ripper, and Mr. Bryan Donkin.

Mr. G. Gerald Stoney replied, and on the motion of the Chairman a vote of thanks was accorded to the authors.

"SOME PARTICULARS OF THE RESULTS OF THE COMPOUND LOCOMOTIVES ON THE BUENOS AIRES GREAT SOUTHERN RAILWAY."

Paper by R. GOULD.

Abstract.

THE question of coal consumption of locomotives becomes in countries like the Argentine Republic, which depends entirely on the imported article, a matter of paramount importance, and an endeavour to secure an economy in this respect led to the trial of the compound engine.

The type of engine adopted on the Great Southern Railway was the two-cylinder "Worsdell and Von Borries," as being the simplest arrangement, and interfering least with the duplication of parts of the standard simple engines previously in service. All these engines, both simple and compound, were built by Messrs. Beyer, Peacock & Co., under the instructions of Messrs. Livesey, Son & Henderson, the Company's consulting engineers.

The first compound engines ordered were erected in 1889, and the results obtained were so excellent that, with the exception of shunting and local traffic engines, no simple engines (either goods or passenger) have since been ordered.

The engines proved easy to handle, exhibited a high economy in coal and water, and, owing to the reduced demand on the boiler, showed less tendency to priming and scale than the original simples. As an offset against these advantages, the first compounds sometimes showed a sluggishness in starting, or an inclination to jib, due to the rapidity with which the automatic "Worsdell and von Borries" starting valve caused compounding to take place, reducing the power by cutting off the live steam from the low pressure cylinder before (in the case of long and heavy trains) the whole weight was fully taken on the drawbars, or the whole train in motion. In this valve the exhaust steam from the high pressure cylinder is held in check by a mushroom valve, which closes automatically by the action of live steam from the boiler, admitted to a pair of small pistons operating on the back of the large mushroom. With this valve closed, no high pressure exhaust steam can pass, and the low pressure cylinder is temporarily fed by a by-pass of live steam from the boiler. The high pressure exhaust being completely bottled up, compounding takes place very rapidly, as the back pressure rising forces open the large mushroom and shuts the by-pass. The

defect was got over by an improvement made in the Company's Works at Buenos Aires in introducing a hollow spindle in the mushroom valve with an escape passage to the chimney, the office of the passage being to relieve the H.P. back pressure to some extent, and so delay compounding.

The effect of the alteration in the intercepting valve was to entirely obviate the tendency to jib previously experienced, and to ensure a certain and easy start, with the maximum power, whilst retaining the automaticity of the valve's action, a most valuable and important feature, putting it out of the power of the driver to work non-compound longer than absolutely necessary, which by some systems is possible, and tends to reduce the economy. This hollow spindle arrangement was found so successful that the intercepting valves of the whole of the compounds—some 109 engines—were so fitted.

The diagrams accompanying showed the principal classes of compound engines on the Great Southern Railway, and also the corresponding simple engines for two classes. Classes 6 and 6A and 7 and 7A compare absolutely. Class 10, designed by the author, for working either goods or heavy passenger trains, represents the most modern engines of the Company, whilst Class 6B shows an engine of special interest as regards the compound question, in that it was constructed from old engines similar to Class 6 at the Company's works. Increasing weights of trains made it necessary to do something to adapt engines—of which the Company possessed a large number—to the heavier demand on their power. The boilers of some of the older engines were replaced by new and larger ones carrying high pressure, the cylinders being at the same time changed for those of increased size, and the engines compounded, the new type being represented in Class 6B.

The engines have proved a great success, being from 25 to 30 per cent. more powerful than the old Class 6 which they supersede, and showing an economy of fuel even better than that of the compounds.

The tabular statement attached shows the coal and lubricant consumption, and also the comparative cost of repairs for the mileages given.

It will be seen from the table that the engines, Class 6A, burn 23 per cent. less coal per axle than their compeers, Class 6, the load being practically equal, whilst the engines, Class 6B, actually show an economy of 37 per cent., but as the latter have hauled heavier trains (which always show a greater economy in consumption per axle hauled) some of this economy must be discounted.

In the case of the engines, Classes 7A and 10, an economy of 14 per cent. over Class 7 is shown, but here again allowance must be made for the fact that the simple engines hauled more axles. The Classes 7A and 10, especially the latter, were employed for the heavier passenger trains, whilst Class 7 were almost entirely employed on goods traffic, not being equal to the task of the heavier passenger work at the higher speeds. If it were not for these circumstances, the Classes 7A and 10 would exhibit an economy equal in amount to that of Classes 6A and 6B. In the matter of lubricants the simple and compounds show practically no difference.

In the comparison of the cost of repairs it must not be forgotten that this is as between the simple and compound engine only. The cost of wages in Buenos Aires is at present about 50 per cent. more than in England, and the material, although imported duty free, has to bear several extra charges, such as freight, packing, insurance, etc., that greatly enhance its cost when delivered to the Company's workshops in Buenos Aires.

The absence of heavy grades on the Buenos Aires Great Southern Railway renders it a favourable field for the compound engine, the grades of importance being in one district only, the bulk of the line being practically straight and level. The character of the traffic, with long runs and full trains as a rule, causing an approximation to the fixed load of a stationary engine, is also favourable for the compound system.

Consumption of Coal and Lubricants for the year 1900.
Engines, Classes 6, 6A *and* 6B, 7, 7A *and* 10.

		Passenger Engine.			Goods Engine.		
		Simple.	Compound.		Simple.	Compound.	
		Class 6	Class 6A	Class 6B	Class 7	Class 7A	Class 10
Coal consumed per train-mile	lbs.	36·00	28·05	29·25	55·68	45·00	40·50
Average weight of trains	tons	162	166	211	624	585	526
Average number of axles per train		25	25·5	32·5	96	90	81
Coal consumed per axle per mile	lbs.	1·44	1·10	0·90	0·58	0·50	0·50
Lubricant consumed per 100 train-miles	lbs.	7·70	6·45	6·28	7·13	7·27	5·96
Lubricants consumed per 100 engine-miles	lbs.	6·38	5·96	5·96	5·57	5·96	5·32
Ratio of coal consumed per axle per mile		100	76·4	62·5	100	86·2	86·2

*Cost of Repairs (General and Maintenance).**
Engines, Classes 6, 6A, 7 *and* 7A.

	Passenger Engine.		Goods Engine.	
	Simple.	Compound.	Simple.	Compound.
	Class 6	Class 6A	Class 7	Class 7A
Number of engines repaired	32	24	22	43
Average cost of repairs per engine per mileage shown	£510	£470	£498	£470
Average number of engine-miles run for above engine repairs	51,034	55,865	54,769	55,224
Average number of engine-miles run per annnm	23,916	28,920	20,556	25,692

* The maintenance does not include wages of running shed fitters, but is for materials and spare parts supplied during service.

The Chairman and Mr. Michael Longridge took part in the Discussion, and on the motion of the Chairman a vote of thanks was accorded to the author.

"THE RATING AND TESTING OF ELECTRICAL MACHINERY."

Paper by Gisbert Kapp.

Abstract.

With the growing application of electricity, the commerce with electrical apparatus forms an important part of the general commerce of every civilised country. Such commerce should be put upon a safe basis by clearly defining the properties of the articles bought and sold. Electrical plant also enters into international commerce, and the question of how it shall be rated and tested appears to be a fit subject for an International Engineering Congress. The rating of electrical machinery must always be influenced by the condition of its use. Thus a tramway motor, rated by the builder at so many H.P., will develop that power, when in service, only occasionally. The time during which this maximum power is required is short if compared with the total running time. Under these conditions the motor will not overheat. If, however, the same motor were used for driving a workshop, and had to give out the rated power continuously, it would break down from overheating. The same type of motor must, therefore, be rated differently in the two cases. The question of efficiency is frequently a source of trouble between buyer and seller, especially in direct coupled generators. The combined efficiency can easily be measured, but not the efficiency of each part separately. According to the method employed, the separate efficiencies found may vary greatly; hence, to protect buyer and seller alike, it is desirable that there should be recognised methods for testing efficiency. These methods should be simple and inexpensive, and cause little disturbance to the regular working of the plant. The German Association of Electrical Engineers has last year appointed a Committee to investigate the question of rating and testing electrical apparatus, and has this year at the annual meeting provisionally adopted the report presented by the Committee. The final adoption has been postponed until the values of the Association "Standards for Rating and Testing Electrical Machinery" have been found out by practical use. These standards are given in an appendix. By issuing them the Association does not desire to interfere in any way between buyer and seller if the two parties agree in detail upon the properties which the articles bought and

sold shall have. The standards are only intended to apply to that extent which is not covered by special conditions of the contract. The standards refer to electric generators, motors, converters, and transformers, but not to switches, fans, and other subsidiary apparatus. As regards the rating, three working conditions are to be distinguished, namely, intermittent use, short time use, and continuous use. The working conditions must be stated on the name plate. The temperature rise is prescribed, and also the extent to which apparatus must be capable of being overloaded. A definite insulation resistance is not required, but a test for dielectric strength by application of high pressure. For testing efficiency eight methods are given, and the maker of the apparatus is at liberty to select any of these as the method under which the efficiency he guarantees shall be tested. The method selected must be stated in the tender.

The Chairman, Mr. R. W. Weekes, Mr. Druitt Halpin, Col. P. E. Huber, Mr. E. C. de Segundo, and Mr. Michael Longridge took part in the Discussion.

The author replied, and on the motion of the Chairman a vote of thanks was accorded to him.

The Meeting was then adjourned.

WEDNESDAY, 4th SEPTEMBER, 1901.

Mr. William H. Maw in the Chair.

"SOME EXPERIENCES AND RESULTS DERIVED FROM THE USE OF HIGHLY SUPER-HEATED STEAM IN ENGINES."

Paper by R. Lenke.

Abstract.

Superheated steam is generated by adding heat to saturated steam. It is a very bad conductor of heat, and has a greater volume per unit of weight than saturated steam. The higher the pressure is, the smaller is the increase of volume. The question may arise whether the increase of volume does not require more additional heat than the benefit derived therefrom is worth. A table has been prepared to show how many B.T.U. less are required to produce one cubic foot of superheated steam than the same amount of saturated steam. For instance, to produce one cubic foot of steam at 115 lbs. pressure and a temperature of 570 deg. Fahrenheit, $\frac{350-297}{350}=15$ per cent, less heat is required; consequently superheating must result in gain. Superheated steam does not condense during the admission period if sufficiently superheated, which is another great advantage.

The use of superheated steam has always effected great economy, and even a few degrees of superheat are sufficient to decrease the steam and coal consumption considerably. To obtain the maximum economy, 660 to 700 deg. is required, and the engines have to be specially designed to withstand this temperature.

The introduction of superheated steam into engines largely influences the expansion of the heated parts. Engines always gave great trouble when the distribution of metal in the cylinders was not uniform, as parts with more metal expanded most, and forced the cylinder walls towards the inside, and made the cylinder out of shape. When using liners in the cylinders, the liners were squeezed in at the ends, decreased the diameter, and jammed the piston body if sufficient clearance was not provided. With steam jackets heated with steam of 500 deg. Fahrenheit, the lubrication ceased as the cylinder walls became overheated; consequently it

was found necessary to do away with the jackets, or, if jackets were already provided, not to pass steam through them. Pistons constructed on the Ramsbottom principle always worked satisfactorily, except in the case of pistons fitted with steel springs when they were in contact with highly superheated steam. Any kind of gun metal gets brittle after a very short time; therefore valves, seats, and all parts in direct contact with superheated steam must be made of cast iron or other suitable mixture. Copper also loses about 40 per cent. of its strength at that temperature; consequently copper bends in pipes are not practicable.

Glands and stuffing boxes at first frightened people, so that engines were constructed single acting to avoid the use of glands, but no serious difficulties have arisen on that account. It is advisable to place the stuffing box as far as possible from the cylinder end to keep it well away from the hottest parts, and to allow of as much radiation as possible. Make sufficient clearance in the neck bush to allow for the expansion of piston rod, and do not use any metal with a melting temperature below that of the steam. Valves and valve gears are influenced in the same way by superheated steam. Valves containing many ribs or different thicknesses of metal (in section), such as plain slide valves or Corliss valves of the usual constructions, are not suitable for high temperatures. A Corliss valve of medium size can stand 480 deg. to 500 deg. Fahrenheit, but no more, and the latter temperature very seldom. The smaller plain slide valves are, the higher temperature they can stand; large slide valves will hardly stand even slightly superheated steam if no provision is made for forced lubrication of the valve face. Piston valves have proved to be most suitable for very high temperatures owing to their uniform distribution of metal, but even with this sort of valve, a certain amount of experience is necessary to get them into good working order. Double-beat valves can also be recommended as being safe, but they require a special arrangement which is not obtainable with all gears.

An engine constructed in accordance with the principles just explained is as safe with superheated steam as any other engine is with saturated steam. The use of superheated steam need by no means be restricted to single acting engines. Besides economy, other important advantages are connected with the utilisation of superheated steam. It makes the steam consumption independent to all intents and purposes of the size of the engine, and it does not require high boiler pressures, 160 lbs. being the highest to be really recommended, as no advantage is to be derived by exceeding it. With regard to the economy to be obtained from engines working with superheated steam, the following comparison of various types of engines may be of assistance. A single cylinder condensing engine with superheated steam works more economically than a compound condensing engine with saturated steam, and it must be remembered that 13½ lbs. of steam per I.H.P. per hour has been reached with a 120 horse-power horizontal single cylinder Corliss engine, at 125 lbs. boiler pressure.

A non-condensing single-cylinder engine with superheated steam has about the same consumption as an average compound condensing engine, as 16 lbs. steam per I.H.P. has been obtained; and non-condensing compound engines have shown consumptions of 14 lbs. per I.H.P. The compound condensing engine is the most economical, and the economy obtained with superheated steam can hardly be equalled by a quadruple expansion engine working at a pressure of 300 lbs. The steam consumption of such an engine —either compound or tandem—at 140 lbs. pressure only, never exceeds 10 lbs. per I.H.P. per hour, and usually remains below, many tests having produced a consumption of 8.5 and 8.8 lbs. per I.H.P. To obtain the better utilisation of these temperatures, and to work under various loads with safety and practically uniform economy, Mr. Schmidt has introduced the receiver heater with automatic valve, the object being to keep the cylinder walls at a steady mean temperature, not higher than will make the lubrication unreliable for different rates of expansion.

The utilisation of superheated steam is recommended in connection with all engines; the only question to be settled is the degree of superheat, which largely depends on local circumstances and on the type of engine, and this matter should be left to the judgment of an experienced engineer.

The following members took part in the Discussion:—the Chairman, Mr. Bryan Donkin, Mr. C. C. Leach, Mr. Henry Lea, Mr. J. Hartley Wicksteed, Mr. Michael Longridge, Professor William Ripper, Professor John Goodman, Mr. E. Hall-Brown, and Professor W. H. Watkinson.

The author replied.

Communications have been received from:—Mr. D. R. Todd, Messrs. Hick, Hargreaves, and Co., and Mr. C. H. Moberley.

On the motion of the Chairman a vote of thanks was accorded to the author.

"A PREMIUM SYSTEM OF REMUNERATING LABOUR."

Paper by JAMES ROWAN.

Abstract.

WITH a view to the adoption of a reliable and satisfactory method of piecework, a premium system was decided upon, of which the following is a description:—

Work, as recorded on a job ticket, is given to a workman on a time allowance, and if he reduces this time allowance his rate of wages per hour, while he is working at the job, is increased by the same percentage as that by which the time allowance has been reduced. It is, of course, apparent that data must be collected for the purpose of arriving at the time to be allowed to do work. For this purpose a special department (Rate-fixing Department) is required, and when instituted, data accumulates very quickly. The period occupied in doing work under the usual time payment conditions may be accepted as the time allowance of the premium system.

When a job is given to a workman, a job ticket is issued to him, with a description of the work to be done, and the time allowed to do it. On completion of the work the job ticket is initialled, and the time of day recorded on it by the foreman, and this is the time of commencing the next job. When the work has been examined and passed by the works inspector, the job ticket is handed to the Rate-fixing Department, which passes the same for payment. In the case of a job being rejected by the inspector, any premium which would otherwise have been earned by the workman, by reason of his having reduced the time allowance, is forfeited. No clerical labour devolves upon the workmen, and very little upon the foremen.

The time allowance for a job given to a workman, rated at say 8d. per hour, is 100 hours, and the actual time occupied on the job amounts to 75 hours. We have then 100 hours at 8d. = 800 pence, against 75 hours at 8d. + 25 per cent. (2d.) = 750 pence, giving the workman a premium = 150 pence, or 2d. per hour, and the employer a reduced cost = 50 pence. Provided the time allowances are equitable to employer and employed, and based on the average attainments of hourly labour, it will be evident from the foregoing that the higher the premium earned by the workman the greater will be the saving in cost. The output of the machines is also increased, but it is a hard matter to put a value to this.

Occasionally a piece of work is begun on one machine and finished on another. The job ticket in a case of this kind is passed by the first to the second operator, and so on until the work is completed, each workman engaged upon it receiving any premium earned, in proportion to the total reduction of time made in completing the whole job. Any number of men may be employed on the same piece of work, and it is not necessary that they should all remain at the work for the same period, because a slump time allowance is made to cover the time of all the men on a job, and the total time spent upon the job fixes the premium percentage, which is used in fixing the premiums of the different men only to the extent of the time each has been employed upon the work; that is, a job for which the time allowance is 1000 hours may be performed in 800 hours—one man might work 100, one 300, and one 400 hours. Each of these men would have his hourly rate increased to the extent of 20 per cent. for the time he had been employed upon the job. The reduction or increase of a workman's hourly rate is not affected, as any change in either of these directions made during the time he is engaged upon a job is calculated at a percentage on his hourly rate or rates. Neither is any difficulty introduced in respect to overtime allowances, as the actual time worked upon a job determines the time upon which a premium is paid. The overtime allowance, which in the Glasgow district is paid at the rate of 50 per cent. on the overtime worked, does not appear in the job ticket as time, being only shown as such in the workmen's time and wages book as a unit to fix the value of the overtime allowances. In the job ticket this allowance appears at its value in money. Nor is there any difficulty presented when working a night shift, as each of the two men at a machine receives a share of premium earned in proportion to the number of hours worked on the job.

It is advisable, where at all possible, that every man should work on his own account; but in cases such as before mentioned, which refer particularly to the erecting department, the inclusion of several men on one job ticket cannot very easily be avoided. It may be mentioned that in the erecting department the apprentices in their first year are not given a job ticket. In their second and third years they are junior apprentices, and half the time that they work is counted; in the fourth and fifth years they are senior apprentices, and three quarters of the time they work is counted. They are allowed the same time as a journeyman. In the machine department apprentices in the fourth and fifth year do the same kind of work that is also done by journeymen, and they are allowed 25 per cent. more than journeymen.

The payment of premiums does not take effect until 5 per cent. premium has been earned, and thereafter only in multiples of 5 per cent. The original time fixed upon as a time allowance has never been reduced, unless there has been a radical change in the method of doing a piece of work. As a rule, the premiums earned by the men have increased since the introduction of this system, sometimes due to the industry, skill, or intelligence exerted by the workman, but oftener due to those exercising a controlling power. The value of this premium system is not limited to a saving in cost of labour by the reduction of the time taken to do work. Numerous instances might be cited where the system has been the means of bringing to notice, through concentration of attention on its development, improved methods of manufacture.

Another feature to which special attention is directed is the use of the job progress card. This card is prepared every morning by the Rate-fixing Department, and indicates the progress which has been made at the various machines; and it may be made of great value to employers and managers. The first column gives the machine numbers, the second column the hours allowed for the jobs in hand, the third column the number of pieces included in each job, the fourth column the hours spent upon the job in hand till 10.30 a.m. on the date the card is prepared, and the fifth column the previous records for similar jobs. The card is therefore an index of the progress of work in each and all machines in operation.

There is a job register book for the machine, brass-finishing, tinsmiths', and smiths' departments, erecting in the works, and fitting on board the machinery in the yard and at the quay. As new jobs occur they are duly registered. Every separate job in the manufacture of a marine engine, from the time the castings and forgings come into the works until the ship leaves after her trial trip, is registered in this book.

The job data book is a record of the work done on each article, and this book now contains a most complete and miscellaneous collection of data in connection with the manufacture of marine engines, and of other work. All whitewashing and painting, shifting of machines, laying down concrete floors, shifting of material from place to place, and many other operations for which, not so long ago, it would have been impossible to fix a time, are now recorded in the job data book.

This system is by no means a final solution of the piecework problem, but it is submitted that this system is a step towards a solution. The value of good and powerful tools is forcibly brought forward; the use of jigs, gauges, etc., is found to be necessary, and old machines are placed at their true value. Meetings with managers and foremen for the discussion of questions arising in the course of manufacture are found to be necessary, and of great value. Better wages are earned by workmen, and more work and better work is got out of the machines. With this knowledge before us we do not hesitate to say that the introduction of a premium system such as described would have an elevating influence upon any workshop where the hourly rate of pay or the ordinary piecework is in use.

From the system above described, three advantages follow. No matter how long a man takes to do the work, whether from novelty, misfortune, misadventure, hanging over his work, or carelessness, he receives his hourly rate of wages. If a man is repeating the same job on the same machine and continually reducing the time of production, he is encouraged, as by all means he should be, to continue doing so. If the time allowance has been fairly fixed at the beginning, the more a man earns the cheaper is the work; in other words, the element of participation is introduced.

The paper is accompanied by specimens of Job Tickets, and pages of Job Registers and Job Data Books.

The Discussion on this paper was taken with that on the papers by Mr. William Thomson, and by Messrs. Weir and Richmond (see p. 123).

The author replied, and on the motion of the Chairman a vote of thanks was accorded to him.

"SOME FACTORS AFFECTING THE ECONOMICAL MANUFACTURE OF MARINE ENGINES."

Paper by WILLIAM THOMSON.

Abstract.

THE most desultory reader of our technical journals cannot fail to be struck with the great and increasing interest which has of late years been taken in the internal economy of our engineering workshops. The object of the following remarks is to draw special attention to certain factors affecting this which have hitherto not received the consideration which their importance warrants. The points particularly referred to are:—

(1) A premium system of labour remuneration.
(2) Good, accurate, and powerful tools.
(3) Arrangement of tools and roomy shops
(4) Standardisation.

The Premium System.—The first and greatest of all these influences is the introduction of the Premium System, which effects nothing short of a complete revolution in a shop. One of the primary results of this system is the establishment of accurate data upon which comparisons are based and deductions made. The annexed Table I., columns 1 and 2, gives a few examples of what the premium system has done in the way of economising time.

Accurate and Powerful Tools.—Another most important factor in the economical production of work is good, powerful, and, very especially, accurate machine tools. The experience of the author's firm in this direction has been one of considerable extent. Old tools have been sold or otherwise disposed of, and new and more powerful machinery substituted. A few examples of the results of this substitution are given in Table I., by comparing columns 2 and 3.

A certain tool made by a first class firm was purchased by the writer's firm three years ago, and after repeated trials it was concluded that it had not adequate belt power, so when a second machine was ordered, an increase in the ratio of gearing of about 28 to 30 per cent. was insisted upon, much against the will of the toolmakers, who considered that the first machine was amply powerful. The result is that the newer machine turns out the same work as the old in 26.5 per cent. less time.

TABLE I.

Description of Work.	Same Machines throughout.			
	(1) Time taken under old Time System.	(2) Time taken on introduction of Premium System.	(3) Time taken in better location with greater facilities.	(4) Record time for the same job.
	hours.	hours.	hours.	hours.
1. Turning conn. rod. 1 off.	43½	36	35	29¼
2. Slotting conn. rods. 3 off.	31	24½	22¼	20
3. Crank webs (finishing holes. 1 off).	7⅔	5¼	4¾	3½
	Old Machines under		New and more powerful Machines (on Premium system).	
	Old Time System.	Premium System.	First time on new Machine	Record Time.
	hours.	hours.	hours.	hours.
4. Turning tunnel shafting. 1 off.	42	29¾	23½	21
5. Turning ecc. rods. 1 off.	22	11½	9	8¼
6. Turning thrust shaft. 1 off.	129	97¼	75	65
7. Finish turning crank shaft. 1 off.	42	34	15	9¾
8. Turning quad. blocks. 13 off.	195	140	91¼	—
9. Slotting sole-plates. 1 off.	70	59¼	41½	35¼
10. Slotting condenser 1 off.	64	56	44	34
11. Slotting H.P. cylinder. 1 off.	45¾	33¾	24	21
12. Ripping out holes in crank webs (1 web). 2 holes.	29	17	9	7
14. Hole - boring main bearing covers for bolts. 12 holes.	45	37	27¼	20
15. Planing six steel slabs for 12 crank webs.	142½	102	65½	—

Arrangement of Tools and Roomy Shops.—The questions of arrangement of tools and roomy shops are closely connected and interdependent, and where these have to be applied to existing buildings they become very difficult ones to settle, and in most cases the result cannot be anything more than a compromise. The question of handling of material, which is the direct result of the arrangement of tools, is one which has not received the attention it deserves, simply on account of the difficulty of getting at the direct loss caused by a poor arrangement. As an example of what can be done by the consideration of these questions, it might be mentioned that after the author's firm laid down their new boiler shop, the work turned out by the light and heavy plating squads was done in 19.6 per cent. less time in the new shops than it had averaged in the old, while the machines turned out their work in 10 per cent. less time than before; the conditions in both cases as regards tools and appliances being exactly the same, except that more room was allowed.

Another example taken from the machine shop illustrates this same point very well. A group of three machines was located in the old machine shop in somewhat cramped and inconvenient positions, but afterwards these machines were shifted to a new machine shop and given lots of room. The results of this new arrangement are given below in the annexed table:—

Machine.	Saving.		Output increased by
	Time.	Money.	
	per cent.	per cent.	per cent.
Double-headed Horizontal Borer	3·9	2·5	4
H. and V. Planer	22·5	14	29
Connecting-rod Lathe	12·8	8·3	14·7

In this comparison the conditions were as nearly as possible the same in both cases, the machines doing the same kind of work; the same men were at the machines, and were working under the premium system in the new shop as in the old. The result was that the men made on an average—which is taken over a long period in both cases—9.3 per cent. more wages; the work was 8.3 per cent. cheaper to the firm, and 15.9 per cent. more work was got out of the same machines, due entirely to a better arrangement and more roomy location of these machines.

Standardisation.—The premium system, with its attendant records, very soon showed up the benefits of having duplicate work, as the saving of time was quite considerable where a run of duplicate or nearly similar pieces was given to a machinist. This was so marked that the question of standardising, not only the details, but the whole engine, was gone into in order to get the full benefit of this, and as patterns began to require renewal the engine was redesigned with this end in view. In carrying out this idea in a new design it was found necessary, not only to consider the engine and its details in relation to themselves alone, but also with special regard to their position in the range of sizes which it was decided to make with a view of keeping down the number of different sizes of details. This practically meant redesigning simultaneously all the sizes of engines made, but a careful analysis and consideration of the requirements to be met, enabled the whole range to be suitably broken up into well-defined groups, each group representing a certain size of main centres, and permitting certain variations of cylinder diameter and stroke within well-defined limits, and suitable for the usual steam pressures. The details, which in each group are never altered, although the cylinders may vary within the group limits, are in very many cases common to several groups, and a large number common to the whole range. This object is always kept in view, in order to provide as much duplicate work as possible. Especially is this so in the case of the very small details, because in these the governing factor in the cost is the wages, not the material—a slight and unimportant variation in size causing a relatively large variation in wages cost; while in the larger details the conditions are reversed, and the material becomes the important cost factor, a relatively small variation in wages covering a very large variation in size.

When, however, duplication of pieces can no longer be carried out on account of the loss of material prohibiting it, much can be done in the way of duplicating similar machined, faced, etc. parts, in different groups. This enables and encourages the use of jigs, which, under other conditions, would not have been warranted by the saving in wages. When even this cannot be done, standardisation by a graded series of similar pieces does much to make the progress of the work through the drawing office and the shops easy and free from the friction and delay incidental to sudden and abrupt changes in design. In the drawing office it has the effect of crystallising that vague thing known as "our practice," and compels it to carry out its work on well-defined lines, thus avoiding expensive and irritating changes and mistakes or oversight.

In the shops, standardisation by its consistency in design familiarises the staff and men with the practice, and enables them to go about each new job with confidence and expedition, knowing that each job as it comes forward, if not a duplicate, will at least be similar, all of which go far to speed up the progress of work through the shop, and thus increase the output. And, above all, by the very fact that the means to effect this calls for the best facilities and most exact workmanship, the result is, that the character of the workmanship is raised besides being cheapened, with satisfactory results to both consumer and manufacturer.

The Discussion on this paper was taken with that on the papers by Mr. James Rowan, and by Messrs. Weir and Richmond (see p. 123).

The author replied, and on the motion of the Chairman a vote of thanks was accorded to him.

"WORKSHOP METHODS: SOME EFFICIENCY FACTORS IN AN ENGINEERING BUSINESS."

Paper by WILLIAM WEIR and J. R. RICHMOND.

Abstract.

So many papers have been written, and so much literature now exists on the equipment and organisation of engineering works, that a brief consideration of some less frequently treated factors in promoting efficiency in the shops may be of interest and possibly of value.

No claim to novelty is made on behalf of these schemes, as several of them are of trans-Atlantic origin, but their success when transplanted to this side shows that much can be done to interest the men and the staff in their work.

The schemes to be described have now been in operation for some time, so that a fair idea can be given of their working results; but the descriptions of the various efficiency factors following are not intended to be exhaustive.

1. *Premium System of Remunerating Labour.*—In an engineering works which for many years has worked only with time wages, the relative wages do not represent the relative values of the men. To remedy this state of affairs it was decided, after considering all the best-known systems of remuneration, to adopt the premium system, for the following reasons:—

(1) The system was simple and easily understood by the men, their extra remuneration being easily calculated by themselves.

(2) The system was comparatively simple in its application, and did not involve a very large additional staff.

(3) It had not the defect of piece-work, that an error in rate fixing is either expensive or discouraging.

(4) It offered a real inducement to the workman to suggest improvements in his machine or tools.

(5) The system in its application gives accurate data for time-keeping and cost-keeping purposes.

After more than three years' experience of the working of the system we have found the following to be among the many advantages gained by its application:—

(1) It has resulted in a largely increased output from our machines for the same labour cost.

(2) An increase in our workmen's average drawings of from 10 to 40 per cent.

(3) In the practically compulsory maintenance of our machines in the highest state of efficiency.

(4) In a greatly increased interest of the men in their work, machines, and equipment, and a fair amount of co-operation in all our schemes for improving our factory.

(5) It has given our foremen a field for the choice of men we never had previously, resulting in the employment of only the best class of steady workmen.

(6) It has caused our foremen to be no longer merely task-masters over the men, but to become more providers of work for them, and inspectors of that work.

2. *The Friction Club.*—To secure a proper discussion on shop problems, and to provide machinery for the systematic carrying out of suggestions and reporting of results, it was decided to inaugurate at our works a club composed not only of foremen, but of all the administrative heads of departments, drawing office, costing department, correspondence department, etc.

When the club was at first proposed its reception was not at all favourable; it was considered by the foremen that reflections would be made by one foreman on the work of another, and that generally it would give rise to internal friction. It was accordingly named the "Friction Club," on the principle that its mission was to be the elimination of friction.

Among the matters dealt with by the club have been the following:—The establishment of a works library; the workmen's suggestion scheme; the admittance and course of apprentices in the works; the lighting of the shops; the distribution of shop labourers; shop hindrances—a report by each foreman on his department, indicating the hindrances interfering with the execution or output of the work of his department; grind stones *versus* emery wheels; wearing of overalls by the men, etc.

3. *The Workmen's Suggestion Scheme.*—Closely allied with the Friction Club is another efficiency factor which has recently been inaugurated in our works, namely, the Workmen's Suggestion Scheme. Encouraged by the success of the first few meetings of the Friction Club, it seemed a logical sequence that suggestions for improvement and reforms should be asked from the workmen themselves. Accordingly a scheme was promoted and discussed by the Friction Club, its purpose being to encourage the workmen to make suggestions for improvements in the shops, and on the work generally. All suggestions are signed with the workman's name and shop number, and are placed by the author in a box provided in the gate-house. The judgment and discussion on the suggestions is conducted at the Friction Club, and also the allocation of the awards, the amount being given according to their decision in one or more sums according to the merits of the suggestions.

During five months the total amount of suggestions received amounts to 60; and of this total the number of suggestions adopted and carried out amounts to about 20 per cent. of those received. The discussion on these suggestions has been most educative, and has resulted in several most excellent shop devices.

4. *The Technical Committee.*—It will be noted that the Workmen's Suggestion Scheme does not include in its scope suggestions for improvement on the designs of the firm's product. Accordingly the function of dealing with designs, etc., lies with a committee comprising the managing director, shop manager, chief draughtsman, and draughtsman on special design. This body is called the Technical Committee, and it deals with the revisal of the designs of the firm's product, the carrying out of experimental work, the tabulation of results, the systematic consideration of complaints and defects, and the criticism and development of new designs.

5. *The Intelligence Department.*—The Intelligence Department deals with the collection of information and data required by the various departments and members of the firm; the indexing, catalogueing, and filing of technical literature, catalogues, cuttings, etc. It secures a systematic perusal of contract advertisements in the technical papers, marks and records openings for the firm's products, and keeps a card index of parties interested or likely to be interested in them.

These brief notes on a few shop schemes are submitted as showing developments in dealing with the minutiæ of an engineering establishment. Their value has been found to consist in providing a medium through which the intelligence and ability of the individual foremen and men are directly ascertainable, and in providing the machinery by which ideas and suggestions are methodically dealt with, followed up, and exhausted, before adoption or rejection.

They have also had the effect of bringing the men and their employers into more direct personal relations, and of creating a certain *esprit de corps* in the shops, the value of which, although not tangible, is nevertheless of a real and gratifying nature.

The Discussion was combined with that on the two previous papers by Mr. Rowan and by Mr. Thomson, and was taken part in by the following members:—The Chairman. Mr. George Livesey, Mr. Wigham Richardson, Mr. Arthur Greenwood, Mr. W. H. Allen, Mr. Alfred Saxon, Mr. Hans Renold, Mr. T. Hurry Riches, and Mr. Wicksteed.

Mr. Rowan, Mr. Thomson, and Mr. J. R. Richmond replied.

On the motion of the Chairman a vote of thanks was accorded to the authors.

A written communication was received from Mr. Philip Bright.

"THE ADOPTION OF THE METRIC SYSTEM IN OUR WORKSHOPS."

Paper by ARTHUR GREENWOOD.

Abstract.

WITH the object of obtaining an expression of opinion of those connected with the mechanical engineering trades assembled in Congress at Glasgow, the author ventured to express his views as to whether the time has not now arrived that some steps should be taken towards the adoption in our workshops, in a more or less complete form, of the metrical system of weights and measurements.

In the first place it will be expedient to consider what advantage would accrue to the mechanical engineering trade of this country by the adoption of the metrical system. If the engineers of this country were to devote themselves simply to the manufacture of engines and machinery required in its own workshops and factories, neither selling nor desiring to sell anything outside the Empire, there would be no reason why they should not continue to muddle on with feet, inches, and hundredweights for all time. It would be our own affair to continue, if we thought fit, a system which has been condemned by most nations of the earth. But it may be assumed that the British mechanical engineer has no desire to be content with any such position. He is determined to continue the efforts he has made to push his manufactures in every market in the world. He has to meet competitors in the countries of Europe and elsewhere where the metric system is universal. Germany has followed the lead of the Latin countries, and has abolished her many standards of feet, and Austria has done the same. Russia continued to honour us for years by using our standards, and still does so to some extent, but in Russia before very long the metric system will be as general as it is in Germany. If the British mechanical engineer is to hold his own in these markets, it is imperative that he should offer goods to conform to their usages, in dimensions and weights. The writer would appeal to those of his engineering colleagues who have doubtless found themselves in the same desperate position he has found himself, provided with a drawing of an elaborate machine carefully scaled to an inch or an inch and a half to a foot, and with probably a very imperfect knowledge of the language of the country with which he desires to

transact business, and endeavouring to answer the numerous questions of an inquisitive and intellectual foreigner who wants to know the dimensions in millimetres and weight in kilograms of particular parts of the machine. Under such circumstances the wonder is that orders could be obtained at all. True, experience has taught many engaged in Continental trade to have plans drawn to tenth scale, thus somewhat mitigating the difficulty here alluded to.

The writer could quote numerous cases of orders from France, Germany, Russia, Japan, and South America, that might have come to England, but for the reason that the purchasers preferred buying machinery which admittedly was not so good or so suited to their requirements, but which conformed to their metric system.

The one serious objection is the cost and trouble of making the change, but this is a difficulty that can be overcome if time is taken to bring about the change. Our legislators so long ago as 1864 made its use permissable, and it is for the leaders in the various trades most concerned to take the next step, and certainly to no trade is it so important as to that of the mechanical engineer; and it is for him to attempt its introduction. It is simply a question of rules, callipers, standards, drills, and reamers, which. after all, is not very serious. The equivalents can be made from existing standard leading screws in lathes by means of change wheels.

The mention of screws at once calls attention to the most serious part of the suggested change; but that difficulty can be easily met. It would be worse than folly to attempt at present to change the standard pitch and form of screw threads so admirably standardized by Whitworth.

Much as one would wish to see the metric system adopted in its entirety, it would be well at present not to advocate any departure from the Whitworth standard thread. The two systems can and do work admirably together side by side in many shops in France, Germany, Russia, and Sweden.

Much has been said lately about the metric system being made compulsory. Parliament has made it permissible, private initiative should demonstrate that it is practical, and should then call upon Parliament to make it compulsory. It would be a mistake to say two years—a period that has been advocated. Twenty years would be nearer the period.

In conclusion the author added briefly his own experience. For the past twenty-five years the metric calliper-gauge has been often quite as familiar in the tool room at the Albion Works as the inch one, and very little difficulty has been met with from the men. In the engineering works in Russia, in which he is interested, both metric and English standards are used, and little difficulty is experienced in their joint use. At the new workshops just completed at the author's works in Leeds for the manufacture of the De Laval steam turbine, the metric standard has been adopted in combination with the Whitworth standard of thread.

The meeting was then adjourned, and the Discussion on Mr. Greenwood's paper was taken on the following day.

THURSDAY, 5th SEPTEMBER, 1901.

Mr. William H. Maw, President, in the Chair.

Discussion on Mr. Greenwood's paper.

The following members took part:—The Chairman, Mr. W. H. Allen, Mr. Hans Renold, Col. P. E. Huber, Professor Archibald Barr, Professor Schröter, and Mr. F. Howard Livens.

The author replied, and on the motion of the Chairman a vote of thanks was accorded to him.

"THE 100-TON UNIVERSAL TESTING MACHINE, WITH VARIABLE ACCUMULATOR, AT THE JAMES WATT LABORATORIES, GLASGOW UNIVERSITY."

Paper by J. Hartley Wicksteed.

Abstract.

The straining frame of this testing machine is worked by a hydraulic ram supplied with water from an accumulator. When the valve between the hydraulic cylinder and the accumulator is open full bore, a test can be made at the rate of 100 inches straining per minute, but the valve can be regulated so as to reduce the speed to a tenth of an inch per minute. The speed is under easy control through a wide range, and it can be altered at pleasure during the progress of a test. Thus the speed may be slow until the elastic limit is reached, and increased during the plastic stage. This facility for varying the speed, together with the absence of all vibration, makes a hydraulic straining gear worked from an accumulator preferable to any other system. It is due to Dr. Kennedy to state that he advocated this system in 1885, and stated in a paper read before the Institution of Civil Engineers (*) that "probably the maximum in steadiness as well as of convenience in working will be found in some such system."

The machine consists essentially of a straining system embraced by a weighing system. The straining system consists

* Proceedings Institution of Civil Engineers, Vol. lxxxviii., page 21.

of the hydraulic cylinder, ram, and notched frame which slide out, carrying the straining crosshead A. The weighing system consists of two long parallel rods with the three crossheads or weighbridges B, C, and D. This parallel frame floats on knife edges. Whatever force comes upon the weighbridges C and D is communicated through the crosshead D to an elbow lever E, the fulcrum of which rests on an anvil at the back of the hydraulic cylinder. The elbow lever communicates the force to the back centre of the steelyard lever above it. The poise-weights on the steelyard measure the forces. In tension tests the specimen is placed between A and C. For compression it is placed between A and B, and if it is placed between C and F it is tested in deflection. The crosshead A, being movable in the notched frame, can be adjusted so as to take long or short specimens either in tension or compression. Upon the ram there is a large nut which can be screwed up tight against the end of the hydraulic cylinder, so as to hold the straining frame out for an unlimited time independent of any leak-off of the water. This device, which enables one to keep the load upon a specimen all through the night or through a vacation, was first introduced for Professor Archibald Elliott, who put down the first 100-ton machine having this provision at the University College, Cardiff.

The torsion apparatus is placed at the back of the main fulcrum of the lever. It is entirely out of the way, and has no connection with the machine except through the torsion specimen itself when it is in position. The torsion gear will exert a twisting moment of 224,000 inch-lbs., and will twist in two a bar of iron $2\frac{1}{2}$ inches in diameter.

The deflection apparatus has swivel supports to prevent indentation, and the presser-foot also has swivelling half-round pieces which spread the pressure over 6 inches of surface, while still allowing the specimen to bend freely; so that, if the distance between the centres of the semi-circles is taken, the test is theoretically the same as if the beam were supported on knife edges at that distance apart, while injury to the section by too intense local pressure is prevented.

The steelyard of this machine has an arrangement of poise-weights which is a combination of the variable jockey-weight starting from the centre of the steelyard, as introduced by Dr. Kennedy on a 50-ton machine, the first of this type, which he put down in his laboratory in Westminster, and of the solid poise ranging over both arms of a double-armed steelyard which the author has used for many years. This combination has been arranged to meet Dr. Barr's desire for a larger scale unit when measuring light loads, and has the effect of giving the same scale unit up to 100 tons, which was obtained on Dr. Kennedy's machine up to 50 tons, without materially lengthening the steelyard. When the machine is being used for loads up to 32 tons, the large poise-weight remains stationary at the short end of the lever, and acts merely as a balance weight to the long end. The variable poise starts from the centre of the lever and travels over the long arm with a scale reading of 4 inches to the ton up to 32 tons. This poise-weight has two removable discs, which reduce it by half, giving a scale reading of 8 inches to the ton up to 16 tons. When the specimen requires more than 32 tons of load, this second poise is lifted clear away from the machine. The balance of the steelyard is not affected owing to the latter being lifted off the line of the fulcrum. The main poise-weight is then liberated from its fixing to the steelyard and engaged with the traversing screw, and travels over the whole range of the steelyard, giving a scale reading of 2 inches to the ton up to 100 tons. At the suggestion of Dr. Barr, these poise-weights ride upon three wheels, of which the two on one side have flanges working in a groove in the rail of the steelyard, to keep the poise from wavering sideways, and a plain single wheel on the other side to support the poise vertically, thus forming a "geometrical guide." There are two scales on the steelyard, one for use with the large solid poise, and the other for use with the variable poise. The poise-weights carry venier scales, which, at the suggestion of Dr. Barr, are attached by hinges to the poise-weights, and rest by their own overhanging weight in V grooves on the scale bar. This insures that the venier scale is always lying close up to the marks of the main scale without the possibility of being injured from want of clearance by the vibrations of the steelyard following upon the fracture of a test piece.

The accumulator has a variable load consisting of ten 4-ton slabs, of which it can deposit any number up to nine on the base, and carry up the remainder. The slabs which it is desired to load on are, at the suggestion of Dr. Barr, hung from the top weight by three rods. This arrangement has been adopted not only on account of its advantages in connection with the testing machine, but to enable the accumulator to be used in connection with other pieces of apparatus, and to increase its value as an apparatus upon which efficiency tests under a great variety of circumstances may be made.

The following members took part in the Discussion:—The Chairman, Professor Archibald Barr, Mr. Arthur Greenwood, and Professor W. Cawthorne Unwin.

The author replied, and on the motion of the Chairman a vote of thanks was accorded to him.

"A REGENERATIVE ACCUMULATOR AND ITS APPLICATION FOR USING EXHAUST STEAM."

Paper by A. Rateau.

Abstract.

The new apparatus referred to in this paper is intended to allow, in a turbine or any other motor, the use of the exhaust steam from machines having intermittent action, such as winding engines or the reversible engines of rolling mills. Engines with intermittent action are well known to be defective in respect of the satisfactory use of the steam, caused by condensation within the cylinders. This inconvenience has no doubt been to a small extent remedied by compounding and also by condensing; but the advantage gained is much less than can be obtained by using the steam at about atmospheric pressure in a turbine provided with a condenser.

The Hon. C. A. Parsons has already urged the use of turbines with low steam pressure, attached to continuously-running steam engines. For instance, if we take a winding engine using 45 kilogrammes (99 lbs.) of steam per B.H.P. (*utile*), which is about the maximum for non-compound engines without condensation, these 45 kilogrammes of steam are sufficient to give, in a steam turbine coupled to a dynamo, an electric power of at least two H.P.; by the application in this case of the regenerative accumulator system, two horse-power is added to the one horse-power of the winding engine.

The difficulty which this apparatus solves is the following:—

The turbine requires to be supplied with a continuous flow of steam, whereas the engine working intermittently delivers it at more or less regular intervals of one or two minutes. A reservoir is therefore required between the two engines. An ordinary reservoir would have excessive dimensions, whilst with the apparatus about to be described this excessive size is avoided, and the cost of erection is relatively small.

This apparatus, which may be called a "regenerative steam-accumulator," serves the purpose of a reservoir. The solid and liquid materials, which it contains, form a storage in which the steam gathers and condenses when arriving in excess, and subsequently re-evaporises during the period when the main engine slackens or stops. The variations in temperature necessitated by the condensation and re-evaporation of steam correspond to the small fluctuations of pressure in the accumulator. The pressure

rises while the apparatus is filling, and falls while it is being emptied. The amplitude of these temperature and pressure oscillations is not great, 3 deg. to 5 deg. C., and 0.10 to 0.15 kg. per cm^2 (1.4 to 2.1 lbs. per square inch). This variation can be limited to any desired range by designing the apparatus sufficiently large in accordance with the periods of running and standing of the main engine.

The apparatus consists of cast-iron annular basins placed one above the other, inside a cylindrical vessel of sheet iron. The steam, which enters the vessel by a pipe near the top, reaches the basin by the central channel. The portion which is not condensed, as well as that which is re-evaporated, descends along the lateral partitions of the vessel, and reaches the pipe leading to the low-pressure machine.

The water carried away by the steam separates out in the upper chamber and falls, first through holes in the top plate, thence from basin to basin by the passages in the overflow to the bottom of the vessel, whence it is discharged by the small pipe, and an automatic steam-trap. The basins are thus always covered with water.

The apparatus is completed with a safety valve and an automatic steam-valve for assisting the turbine by steam direct from the boilers.

By means of this accumulator it is possible to obtain in an ordinary-sized winding-engine plant, an additional motive power of about 500 H.P., with no expense but the cost of installing the turbine and accumulator, which is not great.

An application of 250 H.P. is now in course of erection at the Bruay Mines in the North of France, and will be working in a few months.

The discussion was combined with that on the other paper by M. Rateau (see p. 133).

"EXPERIMENTS ON THE ESCAPE OF STEAM THROUGH CIRCULAR ORIFICES."

Paper by A. RATEAU.

Abstract.

THE design of steam turbines depends upon the knowledge of the laws which determine the escape of steam through converging or converging-diverging orifices. In order to verify exactly the formulæ for the escape of steam, the author undertook, in 1895-1896, at St. Etienne, a series of experiments on this subject, according to a method which gives the greatest possible precision. A short indication of these experiments has been given in the report on steam turbines which the author had the honour to present last year at the International Congress of Applied Mechanics in Paris. But at this time he had not yet completed all the calculations of the results of his experiments, whereas now he is able to give an account of the results. They differ a little from those the author provisionally announced at the Congress of 1900.

Those investigators who experimented before and since the author, namely, Minary and Résal in 1861, Peabody and Kunhard in 1890, Parenty in 1891, Miller and Read in 1895, and Rosenheim in 1900, have all used the same method, which consists of condensing in a surface condenser the steam, which escapes by the orifice for a sufficiently long period, and then weighing the condensed water. But this method, beyond being very laborious, cannot give great precision, because in the first place it is very difficult to keep constant the initial steam-pressure during the whole of the experiments, and the steam, being never absolutely dry, the water which it carries with it is weighed with the condensed water, so that the results found must be generally overestimated.

The author therefore proposed to remove these causes of error so as to obtain exact results within two-thousandths, and to use, besides, sufficiently large orifices to deliver up to more than 900 kg. of steam per hour.

He has reached the desired result by condensing the steam in a stream of water with the use of an ejector-condensor, and by measuring the total yield of water and the initial and final temperatures of this stream. Thus he was able to make all the readings at the same moment, as soon as constant conditions were

obtained; and each experiment did not last more than one or two minutes. It has been possible thus without much trouble to make more than a hundred and forty observations under the most varied conditions.

The paper contains the results of the experiments and diagrams illustrating them. The results agree satisfactorily with the theoretical results.

A combined Discussion was held on the two papers by M. Rateau, and was taken part in by the following members:—The Chairman, Professor A. Stodola, and Mr. Bryan Donkin.

The author replied, and on the motion of the Chairman a vote of thanks was accorded to him.

A communication was received from Mr. Michael Longridge, to which the author also replied in writing.

"POWER REQUIRED TO DRIVE A MARINE ENGINE WORKS."

Paper by James Crichton and W. G. Riddell.

Abstract.

It is not the intention of the writers to attempt to describe a model engine works or driving plant, but rather to enumerate, and show the result of, a few improvements which have been adopted by the firm with which they are connected.

About three years ago it was decided to rearrange the works in a thorough manner, and to fit up a new power installation.

The works had gradually grown during upwards of thirty years, and most of the buildings were in excellent condition, and in no need of reconstruction. The problem to be solved then was how to lay down an economical driving plant, which would conform to the existing conditions, and which would not lead to an unnecessary sacrifice.

At that time the motive power of the works consisted of one marine type boiler working at 80 lbs. pressure, and supplying steam to three vertical compound engines for driving the machinery, and one vertical compound engine for lighting purposes.

The points in favour of so many units were—(1) The saving in steam when running one or two machines at night, which might be driven by one of the small engines; and (2) the fact that, in the event of a breakdown of one engine, the other part of the works were not affected.

It was, however, decided to put in one engine capable of driving and lighting the entire works, and, to meet the difficulty of late work, by driving those machines which experience showed were most likely to be needed at night, with motors which could be connected with current from the Glasgow Corporation supply.

The engine was made to a simple design, and of such strength as to make the fear of a break-down very remote. It is capable, as at present constructed, of developing 260 I.H.P., but this may be increased to 600 I.H.P.

A cylindrical marine boiler, designed to work under either forced or natural draught, was selected as the most suitable type, and has proved itself both economical and reliable. It has a working pressure of 200 lbs. per square inch, and evaporates about 9 lbs. of water per lb. of coal.

The position of the power station was fixed, to a certain extent, by circumstances. The works are situated in a busy part of the city of Glasgow, where ground is costly, and economy of floor space essential. There is no direct communication with any railway, so that all material has to be carted to and from the works. Close proximity to the street was, therefore, an important factor in settling the position of the boiler. The position chosen was between the engine and boiler departments, and as the difference in the floor level of these departments is about six feet, the boiler was placed on the lower level, and the coal tipped over into a bunker in front of it. The ashes were returned by a hydraulic hoist to a receiver on the higher level, under which a cart might be filled automatically.

The engine was placed as near the boiler as possible, with the crank shaft parallel to two of the main lines of shop shafting. Two dynamos were laid down for lighting and driving purposes, and these and the two lines of shafting were connected to the main engine shaft with belts, and all so arranged as to be easily disconnected. Motors were laid down to drive all outlying shafting.

The paper contains full details of the new installation and of the tests which were carried out.

Before instituting a comparison between the old and new systems of driving the works, it may be well to enumerate briefly various units which made up the old installation. These were:—

1. A marine type boiler, working at a pressure of 80 lbs. per square inch. The feed water for the boiler was heated to 205 deg. Fahr., as in the new boiler.

2. Three compound non-condensing engines, indicating collectively, say, 151 I.H.P., for driving purposes.

3. One compound non-condensing engine, for lighting purposes, of, say, 65 I.H.P.

The boiler evaporated about 6.75 lbs. of water per lb. of coal, and the engines used 43.8 lbs. of water per I.H.P. per hour. This gave an average coal consumpt of 6.4 lbs. of coal per I.H.P. per hour.

In calculating the cost of a horse power for a year, the coal used for raising steam for smithy hammers and blower engines has not been taken into account, but the steam for electric lighting has been charged in each case, as it was almost impossible to obtain accurate figures without doing so. It will be seen that the power for electric lighting is much greater in the new than in the old system, and it may be contended that the greater efficiency of a horse power in the new system of driving is partly due to the better lit workshops; but this is a refinement into which the scope of the paper does not admit of investigation.

It now remains to be shown by how much the new system is better than the old—or, in other words, at how much smaller cost it produces work. Since the power in an engine works is expended in removing material from rough castings and forgings, a figure may be found by which different systems may be compared; the system by which the greatest weight of material is removed at the smallest cost being the most efficient. In order to make the grounds of comparison similar, the cuttings produced by machines whose scrap is not in proportion to the power expended—such as shearing machines and saws—are not taken into account; but the weight of all turnings, borings, etc., for a fixed period is divided by the cost of a horse power for the same period, and a money value for the power per ton removed can thus be obtained. From the tables accompanying the paper it will be seen that the cost of removing one ton under the old system of driving was £5.21, and under the new system £2.48, showing a saving by the new system of 52 per cent. Notwithstanding this great saving, it is abundantly clear that the cost may be much further reduced.

The authors hoped that the paper may help to provide a basis on which to calculate the relative efficiency of the driving plant in similar works.

Mr. Alfred Saxon, the Chairman, Mr. W. H. Allen, Mr. Bryan Donkin, and Mr. E. R. Walker took part in the Discussion.

Mr. Crighton replied.

On the motion of the Chairman a vote of thanks was accorded to the authors.

A communication was also received from Mr. Alfred Saxon.

"PNEUMATIC RIVETING, AND OTHER USEFUL APPLICATIONS OF PNEUMATIC TOOLS."

Paper by J. C. Taite.

Abstract.

The author, having been asked to write a short paper on pneumatic tools, and having regard to the comparatively recent one, read by Mr. E. C. Amos, (*) when a lengthy discussion followed, has confined these remarks principally to pneumatic riveting, with special regard to the pneumatic exhibits at the Glasgow Exhibition.

Shell Riveter.—With the introduction of the "Boyer" long-stroke hammer for shell riveting, rivets up to 1½ inches can be successfully knocked down, and the pneumatic holder-up has overcome the difficulties of the old method. The length of the paper does not allow of a full description of the appliance. The most noteworthy feature, however, is that the riveting hammer is mounted, and has a travel of 3⅞ inches in an outer cylinder, to which air is admitted when the hammer trigger is depressed, the pressure acting on a collar surrounding the hammer barrel, shoots the tool forward on to the rivet head, the notched bar at the other end of the rigging being adjusted to provide the reaction necessary for the snap to be continuously pressed on to the rivet, while the percussive riveting action is performed by the hammer. The hammer with its casing is mounted in a spherical bearing which enables it to be turned about through any desired angle within the requisite limits. Another and later development is the No. 9 long-stroke hammer, in which the trigger is dispensed with, and air is admitted by a throttle valve.

Riveter with Tail Piece.—In a riveting hammer with tail piece, largely used in shipyards for beam knees, the length of the tail piece is suited to the spacing of the frames, so that when air is admitted, the hammer jams itself between the rivet and the adjacent beam during the percussive riveting operation, the pneumatic holder-up exerting pressure in a similar manner on the rivet head from the other side.

Deck Riveting.—These tools have been in longer use in the American yards than here, but they are now being gradually introduced, and already on the Clyde a very considerable amount of rivets have been put in with pneumatic tools. Samples of riveting done with pneumatic riveters were exhibited. From the fact that

* Proceedings of the Institution of Mechanical Engineers, 1900, page 119.

a longer rivet is required than that used by hand, it follows that the hole must be more thoroughly filled.

Bridge Work.—For this description of work pneumatic tools are eminently adapted, inasmuch as a satisfactory plant for riveting *in situ*, easily moved from one place to another, has long been wanted. At the construction of the Godaveri Bridge at Rajahmundry, Mr. T. F. G. Walton used pneumatic tools.

Mr. A. B. Manning (Missouri, Kansas, and Texas Railway), in a report to the Committee of the Association of Railway Superintendents of Bridges and Buildings at the Annual Convention, St. Louis, 16th October, 1900, gives the following interesting figures comparing hand and pneumatic riveting:—

"Men with pneumatic riveter will average 500 rivets per day for 8.12 dollars = 33s. 3d., or 1.62 dollars = 6s. 7d. per hundred.

"Men with hand power average 250 rivets per day for 9.20 dollars = 37s. 8d., or 3.68 dollars = 15s. per hundred."

In England the cost of ⅞-inch rivets with pneumatic hammer is 4s. 6d. per 100, as against 10s. 6d. by hand. An ingenious arrangement for carrying a drill, used on the Great Eastern Railway, was referred to; and the same arrangement would be equally useful for drilling holes in the long girders of bridges which cannot be drilled under the ordinary machine.

Locomotive Work.—One of the most recent developments in pneumatic tools is a motor with tube cutter, which is similar to the ordinary drill, but having in addition an air cylinder and piston which forces out a taper mandril, thus pressing the cutting edge of the tool against the tube. By the use of this tool 2¾-inch diameter steel tubes can be cut through in five seconds. The reversible drill with the ordinary tube expander is now also largely used for tube expanding. Pneumatic drills are employed for drilling out stay bolts and re-tapping the holes, and give every satisfaction, a saving of £7 per boiler having been effected in the cost of re-staying the fireboxes at one of the principal yards. Railway wagon floors are riveted pneumatically, a saving of 15s. per wagon being effected. A report from the shops of one of the French railways states the 16-inch manhole doors are cut in the locomotive boilers in fifteen minutes, the plate being 7-16th inch thick, and 1¾ inch tubes are rolled in twenty-seven seconds each.

General Boiler Work.—The long-stroke hammer is used for riveting up the end circumferential seams of Lancashire, Cornish, and vertical boilers, air receivers and super-heaters of water-tube boilers where the hydraulic riveter cannot be used; also on manhole rings, Galloway tubes, combustion chambers and rivets connecting furnace tubes to the front plate, and one firm is employing a gap riveter for the furnaces themselves. These are also used in making large tanks.

With the extension of the use of pneumatic tools the sizes of compressors employed has been materially increased, and many works which have started with either a Westinghouse air pump giving 40 cubic feet of air per minute, or an oscillating compressor giving 60 cubic feet per minute, have now compressors giving 300 to 350.

The fullest advantages in increased output and economy have not yet been reached in this country, owing to the Trades Unions not having, up to the present, allowed rates to be made sufficiently remunerative to the masters, but the enormous saving effected in other countries, particularly by pneumatic riveting, must soon have its effect in this country.

The paper is illustrated by three plates, and accompanied by two appendices.

The Chairman, Mr. T. Harry Riches, Mr. Bell, and Mr. Chester B. Albree, took part in the Discussion.

The author replied, and on the motion of the Chairman a vote of thanks was accorded to him.

A communication was received from Mr. Ewart C. Amos, and Mr. Taite has replied.

"AGRICULTURAL MACHINERY IN THE CANADIAN PAVILION AT THE GLASGOW INTERNATIONAL EXHIBITION, 1901."

Paper by G. Harwood Frost.

Abstract.

AGRICULTURE was originated as an art in Egypt, whence it spread through Greece and Rome to Europe. Until the commencement of the last century, agricultural implements were in much the same state as they were a thousand or more years ago; but the development of the American Continent gave rise to the necessity for labour-saving machinery for farm work, and, as the vast area of arable land in Canada became opened up for cultivation, the manufacture of implements was entered into at home. In the perfection of this class of machinery, Canada has for the past half century held an important position, and is to-day the second largest producing country in the world. There are in Canada about a dozen factories making implements, representing the employment, in all branches, of over 6000 men. In the Canadian pavilion at the G.I.E. six of the largest factories are represented, viz.:—the Massey-Harris Co., Ltd.; the Frost & Wood Co., Ltd.; the Noxon Co., Ltd.; David Maxwell & Sons; the Cockshutt Plow Co.; and the Verity Plow Co. Implements for all purposes are shown, which may be divided into the following classes:—

1. For preparing the ground for seed—ploughs and harrows.
2. For sowing the seed—broadcast seeders and drillers.
3. For cultivation and care of the growing crop—cultivators.
4. For harvesting the crop—mowers, tedders, rakes and loaders for hay, and binders and reapers for grains.

The ploughs are a selection of those made to suit the requirements of Great Britain, and are adapted to meet all the local conditions of the country. They are light, strong, and easily handled.

There are several varieties of harrows shown, viz.—the spring-tooth, spike-tooth, and disc. The first two are made up of independent sections, which may be connected in any number. They are of steel throughout, the former with curved spring teeth, the latter with solid spike teeth. The disc harrow is made of concave discs arranged in two sections, running on frictionless ball bearings, and independently adjustable to any angle. Each section is provided with a section of scrapers to keep the discs clean. This

is used for pulverising and levelling the ground, and also for breaking it after the corn crop has been harvested.

For distributing the seed, two different implements are shown—the broadcast seeder and the drill. The former scatters the seed over the ground, covering it by means of cultivator teeth attached to the rear. The latter distributes the seed through tubes, at the bottom of which are either hoes or shoes to cut the furrow in the ground. The amount of seed sown is regulated by shifting the feed wheel to permit a greater or less quantity of seed to pass from the seed box to the tubes. The hoes are attached without the use of bolts or pins, allowing them to be removed and replaced by cultivator teeth. They may be lifted from the ground either all together or separately.

Of cultivators, only the spring-tooth variety is shown. The teeth are made up in sections pivoted at the front, the depth of cultivation being regulated by spring pressure applied to the sections by a hand lever, which also serves to lift the teeth from the ground.

For harvesting the hay crop, the mower, tedder, rake, and loader are used. The mower cuts the grass, and is made so that the cutting apparatus will follow all irregularities of the ground without interfering with the action of the knife. Frictionless roller bearings are used in the drive wheels and for the intermediate gearing and wearing brass bushings on the cross shaft, where the constant jarring caused by the rapid vibratory motion of the knife renders the use of rollers impracticable. A ball bearing is used to take up the end thrust due to bevel gearing.

The tedder turns the grass, and will do the work of about ten people. It is strongly constructed of steel, and is drawn by one horse. The horse rake is used to gather the hay in rows after it is dried, and then the loader picks up the hay and delivers it on the wagon, where it is placed by hand labour. One of the chief values of the loader is in its ability to save a crop of hay after it has been properly dried in case of a change of weather, when it would be ruined if left to be dealt with by hand.

For harvesting the grain crop, only cutting and tying in bundles are necessary. The reaper performs only one of these operations. The binder performs both, cutting the grain and delivering it in compact bundles of any size desired; but it does not in any way alter the condition or form of the grain itself. There are six distinct operations in the working of the binder—reeling, cutting, elevating, packing, tying, and discharging. The mechanism for each of the first four forms a complete machine in itself, and the last two are operated together. The entire machine is driven from the main drive wheel through a sprocket and chain driving the main gear shaft, thence the power is communicated throughout the machine by means of chain and toothed gearing. The reel picks up the grain, and lays it evenly against the knife, and when cut, on to the moving platform canvas, which carries it to the foot of the elevators. Here it is taken between the upper and the lower elevator canvases and carried to the top, and over a free running roller on to the binder deck. The butter evens the butts and forces the grain down on the deck to within reach of two constantly-moving packers, which pack it tightly against one side of the encircling twine. When the required amount is packed, a trip is pressed throwing the binding mechanism into gear. The needle arm rises through the deck, carrying the twine that completes the circle of the bundle, and laying a double strand across the tying hook. This is given a rapid revolution, which makes a loop, the twine is cut, and a stripping hoop strips off the loop while the ends are held back and drawn through, thereby completing the knot. The bundle is then discharged, the needle arm returns to its place below the deck, and allows the grain that has accumulated behind it to be brought down to the packers.

The reel may be adjusted to pick up grain of all kinds, long, short, or tangled. The binding mechanism may be shifted to place the twine always about the centre of the bundle. The machine may be tilted to cut within an inch of the ground. The size of the bundle may be regulated, and the entire machine may be raised and lowered as desired. Local conditions are met with the open rear, the folding dividers, platform springs, and other arrangements. Roller bearings are used where practicable, and on the crank shaft a wearing bushing is used. The main framework, the wheels, platform, braces, and shafting are all made of steel, making the machine rigid and strong, as well as light.

The self-delivery and the manual-delivery reapers are used on farms where the grain acreage would not warrant the purchase of a binder. On the former, the rakes are driven through a gearing from the main drive wheel, and on the latter the rake and platform are operated by hand.

All farm machinery must be strong and of great capacity, light in weight and in draught, simple in construction and operation, and reasonable in price. Canadian manufacturers have met all these and other requirements, and their goods are sent to all parts of the world, and have everywhere achieved a high reputation for superiority in material, construction, finish, and wearing power.

The Chairman and Mr. Frank S. Courtney took part in the Discussion.

The author replied, and on the motion of the Chairman a vote of thanks was accorded to him.

"THE CASSEL SELF-REGULATING WATER WHEEL."

Paper by E. C. DE SEGUNDO.

Abstract.

THE production of power by the impact of a jet of water under a high head upon buckets atttached to the periphery of a wheel or disc has assumed large dimensions in many parts of the world—notably in Europe and in the United States of America. A number of firms are engaged in the manufacture of this type of water motor with conspicuous success commercially; the capital of these companies is not less than £500,000, and the profits already earned very considerable.

The field for a good water motor is practically unlimited; and it may not be generally known that the energy of falling water has already been employed in Europe to quite a considerable extent. From the statements made in consular reports it appears that at the present day water power is utilised to the following extent:—

France	1,000,000	horse-power.
Italy	600,000	"
Switzerland	600,000	"
Germany	630,000	"
Sweden and Norway	270,000	"
Austria, Hungary	300,000	"
Spain, Portugal, Greece, Turkey, Russia, and Belgium, about...	500,000	"

making a total of about four million horse-power.

The great drawback to the rapid extension of the production of power by falling water is the unreliability of every form of speed governor which has hitherto been placed before the public. The best known example of the impact system is the Pelton wheel. During the last fifteen years a very large number of these wheels have been sold, and the demand shows no sign of diminishing. This type of motor is, under suitable conditions, the cheapest and most efficient power producer known. Experiments at the United States Naval School have demonstrated that the mechanical efficiency at full load can rise as high as 92 per cent., and that at half load to about 85 per cent. Many attempts have been made from time to time to improve the governing of the speed of these

wheels under variation of head or load, but such attempts have not as yet been attended with any marked degree of success.

Water being practically an incompressible fluid possessed of considerable inertia, the variation of the supply of water to the nozzle proportionately to the variations in the load is quite a different problem to that presented under similar circumstances in the steam engine, where an elastic compressible fluid is the motive agent; and it is no exaggeration to say that hitherto all attempts to govern the speed of impact water wheels within small limits have not been satisfactory from a practical point of view. The author made a number of experiments about six years ago with a Pelton wheel directly connected to a dynamo, and driven by water obtained from mains of the London Hydraulic Power Co. at 750 lbs. per square inch; but, owing to the inefficient action of the governing arrangements supplied with the wheel, it was ultimately decided that this form of wheel, when driven in the manner described above, did not form a suitable source of power for electric lighting purposes in cases where any variation of load was likely to occur. Although it is claimed that some improvement has since been made in the method of governing, the result in practice does not appear to show any marked advance.

The author was recently asked to report upon a new system of construction of water motor, which is the invention of Mr. Elmer F. Cassel, of Seattle, Washington, U.S.A., and for the purposes of his investigations he erected a water wheel on this system, and connected it with the supply mains of the London Hydraulic Power Co., thus repeating the type of experiments which he had previously made in this direction. Many speed regulation trials have been made, and Mr. Cassel's system of construction has proved itself to be reliable, and to effect an almost perfect regulation of the speed under variations of load or head of water which are far greater than any which would ever occur in practice.

The construction of the wheel is extremely simple. Two figures accompanying the paper show the arrangement of the wheel at the author's office in London. By judiciously manipulating the water valve, the pressure at the nozzle can be varied to any extent up to about 600 lbs. per square inch. The particular wheel in question is adjusted to acquire a normal speed, when running light, equivalent to the proper proportion of the spouting velocity of a jet of water at 40 lbs. per square inch. Any variation between 40 lbs. per square inch and 400 lbs. per square inch (the maximum pressure registered by the gauge used) did not cause any but a momentary variation of the speed, even when a change of head over the whole range was made as rapidly as possible.

The following trial shows the degree of precision which has been attained in this form of wheel:—

An 18-inch Cassel was erected by the author, and arranged to drive a dynamo, the output of which was taken up by a bank of incandescent electric lamps. Successive variations of 20 per cent. in the load from full load (4.6 E.H.P.) to no load produced no appreciable variation of speed. When the whole load was thrown on or off suddenly, a variation of 1.7 per cent. to 1.8 per cent. from normal took place, but the speed returned to normal in about three seconds. The variation was therefore but momentary.

It will be easily seen that the automatic regulation of speed without reference to the flow of water renders the automatic governing of the water supply a comparatively simple matter.

The Cassel system of water power regulation consists in treating the question as two separate and distinct problems, namely, that the speed of the wheel must be *quickly* controlled to prevent racing or running away; and secondly, the flow of the water in the pipe line must be slowly controlled in order to prevent damage by shock to the pipe line, and to avoid detriment to the driven machinery.

Professor Archibald Barr, Professor John Goodman, and Mr. Bryan Donkin took part in the Discussion.

The author replied, and on the motion of the Chairman a vote of thanks was accorded to him.

A communication was received from Mr. Murray Morrison, to which the author has replied.

On the motion of the Chairman a vote of thanks was accorded to the Glasgow University Students' Union for the use of their hall during the meeting, and to all who had helped in the management of the Congress.

The proceedings then terminated, and the business of the Section was brought to a close.

SUMMARY OF PROCEEDINGS

OF

Section IV.—Naval Architecture and Marine Engineering.*

TUESDAY, 3rd SEPTEMBER, 1901.

The Right Hon. the Earl of Glasgow, LL.D., G.C.M.G., in the Chair.

The Chairman opened the proceedings of the Section with a few words of welcome to the many eminent naval architects from foreign countries who had honoured the meeting with their presence.

"THE CHIEF CHARACTERISTICS OF THE NAVAL DEVELOPMENT OF THE NINETEENTH CENTURY."

Paper by Sir Nathaniel Barnaby, K.C.B.

Abstract.

The century through which we have passed will be known to future generations as the age of steam. During the century, men have passed from the speeds on the water which have endured for long ages without change, to speeds considerably more than twice as great as the highest which had been reached before; and, connected with these steam speeds and with the independence of the elements which steam gave to the navigator, roads have been opened for commerce by new waterways connecting separated oceans.

It may possibly be known also as the age of steel. It was the abandonment of wood as a building material which made it possible to give to ships great length and gigantic propelling machinery. With wood as the building material, neither great dimensions nor high speed could have been given to screw-propelled ocean steamships. But it is proposed to direct attention to some less marked characteristics. They are—

---

* The Proceedings of this Section have not been published in full. Reports appear in *Engineering* of September 6th, and in other technical papers.

1. The separation and differentiation in the types of ships for commerce and for war were the principal notes of the last half of the century. During the earlier half of the century and for all time before that, ships for commerce and for war were built of the same materials, were subject to the same injuries, and were capable of being as successfully defended as ships of war.

It was the use of iron in the construction of the merchant ship which created the first ground of distrust on the part of the Lords of War. They held that iron-built ships would never be able to fight, and all provision for arming the mail ships and putting them under military control therefore ceased.

The use of side armour on the fighting ship put the merchant ship more completely out of court, so that the naval war authorities ceased to take any interest in the way in which the merchant ship was built or manned; and the two classes drifted so far apart that there really was, in the end, no fighting power in even the largest merchant ships of any country.

2. The century has, however, seen, during the last five and twenty years, distinct signs of a tendency to suppress this new feature and raise the position of the merchant ship. So we see again the ships for war and for commerce built of the same materials, with equal speeds, and capable of being alike efficiently armed and defended. The merchant ship will more easily reach high speeds and wide ranges of operations than the war cruiser, and will always be adopting for its own purposes devices for increasing both these advantages. It will always have, moreover, this great feature in its favour, that, as the march of events gradually forces slower ships out from the front rank, they will be able to find satisfactory employment in inferior ranks. But the regular war cruiser must be first or nowhere. It is clear, therefore, that the war navies must incorporate these fast merchant ships.

During the last session of the Institution of Naval Architects and Marine Engineers, held in this city in June, it was resolved that a committee of Admiralty officials, shipowners, and shipbuilders ought to be formed to discuss the best method of constructing a combined naval and mercantile marine. Steps will be taken by the Council of the Institution to give effect to this, and it will be obvious that it may be efficiently helped by expressions of sympathy in this matter on the part of other Institutions of Engineers.

3. Another characteristic is the appearance of a desire, and of measures for giving effect to it, that war should be rendered as little onerous as possible to the Powers with which the belligerents remain at peace, and that the operations of war should be confined to the regularly organised forces of the belligerents.

This desire led to the rule, "Free ships, free goods," and to the abolishment of privateering, rules which now so widely prevail. It led further to the acceptance by several of the foremost maritime Powers that "the private property of subjects or citizens of a belligerent on the high seas should be exempted from seizure by the public armed vessels of the other belligerent, except it be contraband."

Although this has not advanced beyond a pious opinion strongly held, it is apparently ripe for International acceptance.

4. The century has been marked by the rise of new naval Powers, which have either achieved or are destined to greatness.

5. It has been marked by the influence of international co-operation upon naval development, as, for example, by the formation and labours of such societies as those constituting this Congress.

Col. John Scott, Professor Capper, and Professor Biles took part in the Discussion.

On the motion of the Chairman a vote of thanks was accorded to the author.

"APPROXIMATE RULES FOR THE DETERMINATION OF THE DISPLACEMENT AND DIMENSIONS OF A SHIP IN ACCORDANCE WITH A GIVEN PROGRAMME OF REQUIREMENTS."

Paper by J. A. Normand.

Abstract.

The problem which forms the subject of this paper is the one most frequently proposed to the naval architect, but, although much has been written on the subject, no simple method of solving this problem has hitherto been shown.

The proposed method is, like the more complicated ones already in use, based upon the equation of displacement.

When the plans for a new vessel are to be laid down, the surest and simplest process is to take as a type one or more vessels differing as little as possible from the one to be designed—preferably an existing vessel, of which all the data, partial weights, and results are well known, so that the calculations may be based on facts and not on hypotheses—and to work out the changes required by the slight differences between the programmes of the old and the new ship. The possible errors are limited in that case to those that may be committed on slight differences.

If the vessel to be designed is a cargo or passenger boat, or a yacht, size generally forms part of the programme. Not so in a war vessel, where size and displacement must, in most cases, be reduced to a minimum. This paper deals especially with war vessels, although the proposed rules may be used with great advantage for all kinds of ships.

If the speed is not altered, but only weights added or suppressed, the author investigates what the displacement of the new ship will be, supposing her to be exactly similar to, and differing only by scale from, the one chosen as type, the water-line remaining at the same relative height in order that the fineness of the lines be not altered. The following simple relation between the weights first added to the vessel chosen as type, and the ultimate increase of displacement, is arrived at, viz.: —

The plus or minus difference of displacement must be equal to the plus or minus difference of weights, as calculated for the vessel chosen as type, multiplied by a co-efficient k, which can be exactly determined, and is nearly constant for all classes of vessels, its

mean value being about 3.60 for the general conditions of the programme to be fulfilled.

Knowing by this very simple rule the approximate displacement of the ship to be designed, it is easy to calculate the dimensions, horse power, weights of hull, machinery, coals, etc., by reference to the same elements in the type vessel.

The author then gives instances of the application of these rules. Taking as type a cruiser of the "Diadem" class, of which all particulars are obtainable, such problems as the following are considered in detail, viz. :—

What would be the displacement and dimensions of a similar vessel—

(1) If small tube boilers were substituted for Bellevilles, supposing the speed, steaming distance, thickness and distribution of armour, weight of guns and ammunition, etc., to remain the same?

(2) If cylindrical boilers were substituted for Bellevilles, the other conditions, as above, remaining the same?

(3) If small tube boilers were substituted for Bellevilles, the weight of guns, etc., reduced by 35 tons, the weight of armour reduced by 20 tons, and the steaming distance increased by 30 per cent., while the speed remained the same?

The few problems which were solved by the new method are sufficient to show how easily it may be applied. It elucidates very simply a question which most people, and even some naval architects, do not clearly realise—the extreme importance of lightness in a war vessel. The immense advantages resulting from a reduction in the weights of war vessels will certainly lead, sooner or later, to the adoption, not of small water-tube boilers, but of mean water-tube ones of some type or other, capable of standing a high rate of combustion. Even this substitution will not be sufficient if the race for speed continues. Steel of high tensile strength will be needed for the hulls of large vessels; but the greater part of the advantages to be derived from its use will be lost until equally strong steel, not hardening when rivetted hot, can be produced commercially and with certainty.

M. Emile Bertin, Mr. James Hamilton, Mr. R. T. Napier, and Professor J. H. Biles took part in the Discussion.

On the motion of the Chairman a vote of thanks was accorded to the author.

"THE HYDRAULICS OF THE RESISTANCE OF SHIPS."

Paper by E. C. THRUPP.

Abstract.

THIS paper investigates a phenomenon in the laws of motion of water which may be briefly stated as a divergence from the laws of stream line motion enunciated by Poiseuille, Osborne Reynolds, and others, when the dimensions of the channels give hydraulic radii exceeding two inches.

It is well known that the friction of water moving in small pipes at low velocities is approximately proportioned to the velocity, and that at a certain "critical velocity" the law changes, and the friction varies as V^3 or V^4, and at still higher velocities it settles down to V^2 or $V^{1.85}$

Osborne Reynolds enunciated the "law" that the critical velocity varied in simple *inverse proportion* to the hydraulic radius.

The author has found, by experiments on channels of various sizes up to about 8 feet in hydraulic radius, that for radii of 2 inches and upwards the critical velocity *increases* with the hydraulic radius, and he finds numerous indications of the phenomenon in published records of hydraulic experiments, notably in those of the Mississippi River Commission, carried out at Carrollton, in water about 60 feet deep.

Confirmation of the author's conclusions is afforded by a study of the nature of channel beds, and the scouring power and silt-carrying capacity of water flowing at various depths. The depths and velocities which occur in channels where the beds are accumulating very fine silt agree closely with the critical velocity conditions arrived at from surface slope and velocity measurements. The scour is, therefore, clearly due to the change from stream line to sinuous motion.

Mathematical theories as to the velocity required to move solid particles in water have entirely failed to agree with observed facts in large channels, for there are innumerable instances where the velocities (at the bottom of the channels) are sufficient, according to ordinary text book theories, to roll along large cubical boulders, whereas, in fact, they hardly disturb fine silt or sand.

The problem of the resistance of ships is intimately connected with this critical point phenomenon, and also with certain wave

motions, which the author has also found experimentally to differ from the accounts given by some eminent writers.

It is generally accepted that the experimental model system of estimating a ship's resistance according to Froude's method, based on Newton's principles of "similar motions," is the best system known; but even that method requires some "doctoring" to make it fit in with the results of actual trials. The discrepancies are due, in the author's opinion, to the fact that the motions of the water past the model and past the ship at the so-called "corresponding speeds" are not precisely *similar motions*, owing to the critical velocity law which rules the motions within the limits of speed at which such trials are usually made.

The custom of calculating all the known sources of resistance on some definite basis, and of calling all the rest "wave-making resistance," is condemned, and the author contends that the assumptions usually made in estimating the "skin friction" of ships are not warranted by ascertained facts in other departments by hydraulic science. For instance, it can be shown that the friction per square foot of wetted surface in a pipe or open channel depends not only upon the velocity of the water, but upon the dimensions of the channel, and the nature of the motion.

To attribute all the obscure features of ship resistance to "wave action" is misleading, as the production of waves may be only an effect, and not the cause of the obscurity.

It is true that Froude's experiments with models having various lengths of parallel body showed great fluctuations in resistance coincident with the existence or absence of the crest of a transverse wave near the stern of the model, but the question arises as to what the position of this wave depends upon. The fact that some ships have had their performances improved by the insertion of an extra piece of parallel body, and also the experiments of De Mas in France on various lengths of canal boats, go to show that large difference in lengths may make practically no difference in the resistance.

The author describes some experiments he has made on the motion of groups of waves resembling the transverse waves which accompany a ship, and which prove to be quite different from the laws of motion of groups of waves as held by Lord Kelvin, Lord Rayleigh, Osborne Reynolds and others; and he dissents from many of the statements they have made with regard to this subject, and gives a description of the main features of the currents and waves produced by the motion of a ship, which are, in his opinion, more consistent with all the observed facts available for the formation of a correct theory of the hydraulics of the resistance of ships.

The paper was accompanied by illustrated diagrams representing the results of the author's experiments, and other matters.

Professor H. S. Hele-Shaw and Mr. J. M. Adam took part in the Discussion; and the author replied.

On the motion of the Chairman a vote of thanks was accorded to the author.

The meeting was then adjourned.

WEDNESDAY, 4th SEPTEMBER, 1901.

The Right Hon. the EARL OF GLASGOW, LL.D., G.C.M.G., in the Chair.

"SHIPYARD EQUIPMENT."

Paper by Professor J. H. BILES.

Abstract.

THE necessity for constant improvement in labour-saving tools was called attention to. The division of the work of a shipyard into iron and wood work sections was discussed, and further consideration was given only to some iron working tools. The structure of a ship, and the method of shaping the different parts, were described. The following machines and tools were described and illustrations shown:—Punching, shearing, countersinking, and planing machines; plate-bending rolls and straightening rolls; plate-edge planing, beam bending, joggling, and bevelling machines; hydraulic punching, shearing, flanging, and riveting machines; pneumatic tools for riveting and boring, and a few electric driven tools.

The general subject of the cost of production, and the relation between the design of structure and the shipyard plant, were discussed. The general arrangement of plant in a shipyard was described, and the principal considerations determining the relative positions of, numbers, and power of different machines were discussed. The general transportation plant of a shipyard was described. The illustrations, about eighty in number, were all lantern slides.

The Discussion was combined with that on the paper by Mr. Robert Robertson (see p. 158).

The author replied, and on the motion of the Chairman a vote of thanks was accorded to him.

"ELECTRICAL POWER SUPPLY IN SHIPBUILDING YARDS AND MARINE ENGINE WORKS."

Paper by ROBERT ROBERTSON, B.Sc.

Abstract.

WORKS of this kind, like all others, differ in size, in arrangement, and in many other respects so much that each case must be taken and considered in detail by itself before any reliable conclusion can be arrived at as to the advantages in that particular instance.

The conditions ruling in a shipyard are so different from those in an engine works that it will be convenient to consider the two separately, and also to take the latter part first.

ENGINE WORKS.—The advantages claimed for electrical driving in marine engine works may be conveniently classified under three heads, viz.:—(1) Saving in cost of power; (2) Flexibility of the system; (3) Increased output.

1. In considering this subject, the saving in cost of power is too often looked upon as the only advantage to be gained, and the advantage is treated lightly because the whole cost of power in a work of this class only bears a very small proportion to the other costs of production. It must, however, be evident that the advantages gained under the other heads are such as to result in substantial increase of output and diminished cost of production, they are of much greater importance than the saving in cost of power.

The saving to be effected in the cost of power may be considered under two heads: (1) The saving in power production; and (2) the saving in distribution.

By the adoption of a central power plant with boilers and engines grouped together upon a suitable site, it is possible to use with advantage all appliances for getting cheap power, and thereby effect considerable reduction in the amount of steam used per horse power generated. This saving is placed by several authorities, who have investigated the subject, at from 30 to 50 per cent.

In order to appreciate the saving under the head of distribution, it is necessary to consider the circumstances in each case. Under the old system of driving, this loss consists of evaporation from steam pipes, losses in main shafts, belting, bevel gearings, etc.; and

it is evident that these losses are practically constant at all loads, and bear a very much higher proportion to the total power when only partial load is on the plant.

In the case of the electrical system the distribution by means of wires or cables takes the place of the steam pipes, main shafts, main belts, bevel gearing, leaving in most cases only short lengths of straight shafts. The losses in the wires are such that they fall off in greater proportion than the load falls off, and therefore bear a more or less constant proportion to the power being used.

The saving to be effected by this means at full load will probably not exceed five or ten per cent., but at all other times, when the load is other than the maximum, the saving will be much greater.

2. Under the second head of the advantages of this system of power—*i.e.*, flexibility—little need be said further than indicating the possibilities.

The use of separate motors for large tools, or for small groups of tools, enables these to be placed in the most suitable positions for convenient handling of the materials, irrespective of the position or direction of line shafts, etc. The advantages to be got by the extended use of portable tools, more especially in heavy work, is very great, the time and labour of shifting and setting the tools in many instances being very much less than if the heavy castings have themselves to be shifted frequently. The flexibility of the system is also of great advantage in the extension of works.

3. It is more difficult to appreciate the advantage of increased output, and it is by no means easy to demonstrate it, but there has been, on various occasions when the subject has been discussed, considerable testimony by those who have adopted the system, that not only a very substantial increase of output is obtained, but also at a very considerable reduction of cost for labour. Among other causes for this improvement we have already seen the advantage of being able to place tools in the most convenient situations, and the possible large use of portable and semi-portable tools, several of which may be at work on the same piece of machinery simultaneously. The absence of a considerable amount of belting and shafting also admits of more extended and free use of overhead cranes, and such cranes are more speedily operated themselves by electric power. A further advantage is obtained from the fact that individual machines can more easily be driven at their most economical speed by electric driving.

SHIPYARDS.—It is evident that all the advantages claimed in the case of engine works are greatly enhanced when the working of shipyards is considered. The same principles may be applied as in the other case, and it is unnecessary to consider them more in detail; but the advantages to be obtained by the flexibility of the system reach their maximum in a shipyard as compared with any other industry. The tools themselves are, as a rule, of a heavy class, which can most conveniently and economically be driven by independent motors, and may thus be disposed in such positions as to reduce to a minimum the handling of the raw material. With the increasing size of ships, and corresponding increase of weights of the component parts, this is of the greatest importance.

Further advantages may be obtained in a shipyard by the facility with which electricity may be applied to all forms of gantries, cranes, or other lifting appliances used in the erection of ships. Portable tools may be applied on board the ships during construction, and temporary workshops with semi-portable tools fitted up on board.

EQUIPMENT.—Here, also, it is only possible to deal with general principles. Broadly speaking, there are two systems which may be adopted, viz., the continuous current system, and the multi-phase alternating current system. As regards the actual driving, either system is suitable for the shipbuilding industry, and each system has advantages peculiarly its own; the outstanding advantage in favour of the continuous current is the fact that motors of this class can more easily be adapted to run at varying speeds.

On the other hand, there are several advantages with multi-phase current for work of this class. The starting arrangements are very simple, especially with small motors; the moving parts are of strong mechanical construction, and less liable to damage by overloading; and there are no brushes and commutators requiring attention. There is very little between the systems as regards cost and efficiency.

The question as to whether single motors on each machine tool, or group driving by means of short shafts should be adopted is of the greatest importance as regards economy in working. In the class of works under consideration there is, as a rule, not much difficulty in arriving at a decision. Unless in the case of special portable tools, it is not economical to employ motors of less than five horse power. Below this size the cost of motors per horse power increases very rapidly and their efficiency decreases very rapidly, and in addition, where machines are worked intermittently and at varying powers, it is possible by suitable grouping to arrange a motor of, say, 10 or 20 horse power upon a shaft to drive machines which, if supplied by separate motors, would require an aggregate of more than double that power. Single motors may be employed in the shipyard to greater advantage, but the tools in this case are of such a class that in very few cases will smaller motors than five horse power be required.

It is impossible to consider the question of cost of installation in a general way, as it will vary in every case according to circumstances.

In conclusion, it may be confidently asserted that in the case of starting new engine shops and shippards, it is undoubtedly the best policy to adopt electrical power, and that in most cases it will pay to make the change in existing works.

The Discussion on this paper was combined with that on the paper by Professor J. H. Biles.

Mr. H. M. Napier and Mr. de Rusett took part in the Discussion.

The author replied, and on the motion of the Chairman a vote of thanks was accorded to him.

"A MEMORANDUM ON FLOATING DOCKS."

Paper by T. Gibson Bowles, M.P.

Abstract.

The floating dock has developed greatly and rapidly. It has passed through the same phases as ships; has grown from wood to iron, and from iron to steel; has increased in size, altered in form, and been as much improved in design and details as ships themselves. The older types, such as the old Bermuda Dock, which is shaped like a capital U, with double sides and bottom, are even more obsolete than a battle-ship of that date (1868) would now be; nor could that dock be thought of to-day as an adequate provision for to-day's warships.

The original floating docks were long iron vessels, with gates at each end, the whole thing floating on the water. The ship entered the dock at one end; the gate was swung to behind her; she was shored up inside, and the water inside the dock pumped away from around her. This was a dock differing from the graving dock only in that it floated on the water instead of being hollowed out of the ground.

Then came the lifting dock with open ends, which first sank in the water, was then pumped out, and raised the ship as it rose. Its typical form to-day is that of the large and powerful new Bermuda Dock, which is the type probably best adapted for general use.

There are also the L-shaped docks, which are of three kinds:—(1) Off-shore docks connected by booms to piles ashore; (2) Depositing docks with a floating outrigger; (3) Off-shore docks with a floating outrigger. The two latter are entirely floating, and wholly free from all connection with the shore.

The floating dock is by no means in an experimental stage. It has been at work for a century at least, though, like all other floating structures, it has only in comparatively recent days been adapted to modern needs. It has been adopted by the most capable naval authorities, private and public, of all the maritime nations.

Nor has experience of floating docks brought any decrease of confidence in them, but the contrary. We find that the British Government has recently ordered a new and larger one, costing £195,000 delivered on the Tyne, or £230,000 in all, delivered

at Bermuda. For it is to be towed to Bermuda to take the place of the one already there. This dock is self-docking, and is 545 feet over keel blocks, entrance 100 feet, capable of taking vessels drawing 33 feet, with a lifting power of 15,500 tons. We also find that the United States Government has recently ordered one 525 feet over blocks, entrance 100 feet, with lifting power up to 18,000 tons, for New Orleans, where these docks have been tried since 1866.

The floating dock has admittedly the merit of being capable of use in places where a graving dock would be either impossible or difficult of construction. But even in a place where either a graving dock or a floating dock is equally possible, the latter has very important advantages of its own which do not belong to the former, as is evidenced by the fact that at many places where graving docks are not only possible, but are already in existence, floating docks have been added to them instead of other graving docks.

The qualities of importance to be considered in a comparison of docks may be said to be seven in number. They appear to be:—

1. Advantages and disadvantages of the general mechanical principle employed.
2. Cost, in which is included original cost, cost of up-keep, and cost of working.
3. Time required for the construction of the dock.
4. Mobility of the dock.
5. Adaptability of the dock for its work under all conditions.
6. Certainty in construction of the dock, both as to time and cost.
7. Length of time required to berth and safely dock an ordinary vessel under ordinary circumstances.

Each of the above qualities was then discussed in detail in the paper.

Finally, to sum up, the floating dock has been adopted, improved, readopted, and continually used by the most capable naval authorities, public and private, of all the great maritime nations; it is used, and always successfully, at places where no other kind of dock can be placed, and at places where there are graving docks in constant work as well; it is mechanically advantageous over the graving dock to the extent of requiring only about one-fourth the latter's horse power to do the same work; it costs but one-third as much as the graving dock of similar size to construct; it is but very little, if any, more expensive to keep up, and its maintenance expenses amount to but $1\frac{1}{4}$ per cent. per annum on its prime cost; it may be constructed and delivered in a year with certainty; it may be towed and moved, with or without a ship on board, as required in smooth water; it can adapt itself to any condition of list or strain in which a wounded ship might find herself; its total lifting power, by which alone it is limited, may always be exercised upon *any* vessel to the full; the contract for it—since there is nothing unforeseen to be allowed for—is certain to be be adhered to; and it will berth and dock a ship quicker and more advantageously (except only in case she required the serious disturbance of her heaviest weights) than a graving dock of equal capacity.

Mr. Lyonel Clark, Admiral Sir Gerard Noel, K.C.M.G., Mr. E. H. Tennyson d'Eyncourt, and Mr. R. T. Napier took part in the Discussion.

On the motion of the Chairman a vote of thanks was accorded to the author.

The meeting was then adjourned.

THURSDAY, 5th SEPTEMBER, 1901.

Mr. John Inglis, LL.D., Vice-Chairman, in the Chair.

"THE MODERN STEAMBOAT EQUIPMENT OF WARSHIPS."

Paper by E. C. Carnt.

Abstract.

In order that the development of the present steamboat equipment of warships may be followed, it seems necessary to refer back to the time when steam was in its infancy in our navy. Up to the years 1865-66, steam launches in use in the British Navy were few, and those few slow and heavy. They were 42 feet long, about 11 feet beam, and had a speed of 7½ to 8 knots; the hulls were built in the Royal Dockyards, and the machinery by firms of the standing of John Penn, Maudslay & Field, J & G. Rennie, etc. The rowing and sailing boats which formed the equipment of war vessels had, in the meantime, been brought to a high pitch of perfection, particularly as regards the small sailing lifeboats which were attached to nearly every ship in the Navy.

The application of steam machinery to these hulls was the next step in the development of the modern boat, and, as a result of experiments made in 1864 to 1866, by Mr. John Samuel White, at Cowes, the first 27-foot steam cutter was constructed and tried by the Admiralty, with a view to use for the special boat work required in connection with surveying service. This boat was successful, and a larger one, 36 feet long, built on the same principle, was ordered, and tried in 1867. She, also, was satisfactory, with a speed of 8½ knots, and became the standard boat until 1878. In that year greater speed was required; the 48-foot vedette boat was evolved, and a speed of 13 knots obtained.

Further developments led to the patent turnabout, double rudder boat, and in 1882 a 42-foot boat on this principle was completed and put on service. In 1883 the dimensions further increased to 56 feet length, and the speed to 15½ knots under certain conditions, the turnabout principle being retained.

From then onward there have been gradual changes, and the adoption of water-tube boilers, with the result that a speed of 16 knots can now be attained with a service 56-foot vedette boat under trial conditions.

In foreign navies, a greater desire for speed has led to further developments, and the Japanese Navy now possesses four of the finest vedette boats in the world, 56 feet long, 9 feet 6 inches broad, with a speed, under specified official conditions, of 18½ knots per hour.

This represents a record of 37 years' work on the same class of vessel, and gives us the development from a 27-foot cutter with a speed of 7½ knots, to a 56-foot vedette boat with a speed of 18½ knots.

Col. N. Soliani, Professor J. H. Biles, Mr. Corner, and the Chairman took part in the Discussion.

The author replied, and on the motion of the Chairman a vote of thanks was accorded to him.

"SOME GRAPHIC ANALYSES OF PROPELLOR REACTIONS."

Paper by J. MILLEN ADAM.

Abstract.

THE paper concentrates attention on the propellor and the fluid which passes through it as a conservative system, and describes a rotating screw as an instrument to induce from the surrounding element on one side, and to produce distinct from the surrounding element on the other side, a homogeneous current relative to itself, flowing parallel with the axis of rotation, and receiving therefrom corresponding reactions.

The difference between the screw pitch in relation to the pool within which the propellor is found and the resultant ship speed, provides the angle of incidence without which no useful energy would be employed, and a probable explanation of apparent negative slip is given. Reasons were also adduced for the non-success of attempts to adopt gaining pitches, and it is shown that a non-gaining pitch is an essential feature of the helical screw. With the assistance of a series of geometrical diagrams, the evolution was traced from the inclined plane with its simple reactions to the twisted rotating vane, and the gradual but complete divergence of its system of reaction from the type; and the necessity was shown for a modification of the surfaces to meet the various complications demonstrated.

The angles of incidence over the whole superficies of the blade must be such in relation to the attacking fluid that the acceleration shall be normal to the disc area, and it is not so upon the helical screw. The angle of incidence has an outward radial component, which was graphically described; also any line of tangential escape was shown to be a convex curve. Although the water of the race does not disperse much because there is nothing to take its place, an instantaneous deflection or tendency to deflect indicates loss of energy, which can be as surely dissipated by concussion as by translation of matter. Propulsive thrust is upon the propellor and nowhere else, and the direction of the resistances bearing thereon is of primary importance.

A further series of diagrams and models traced the evolution of an ideal vane from a curve whose entering tangent is parallel with the attack, and rises on vertical equidistant ordinates whose

successive lengths are as the squares of units in arithmetical progression, giving equal acceleration, at right angles to the force, in unit of time. Such a vane is found only on the surface of a cone rotated on an axis passing through the apex of the cone, but inclined to the conic axis. Besides possessing this ideal gaining pitch, the vane described was shown to have a constant centripetal component in every angle of incidence, corresponding to a moving force directed towards the centre of rotation, altering the acceleration in direction but not in magnitude, and therefore dissipating no power. Such a vane was also shown to yield a total acceleration equal between parallel edges, or with practically constant width from root to tip. The simplicity of the conic form for geometrical computations, also the flexibility of the figure in respect of generating angle and angle of inclination, were also shown to be features of advantage.

Mr. E. Hall Brown, Mr. E. C. Thrupp, Col. John Scott, C.B., and Mr. E. R. Mumford took part in the Discussion.

The author replied, and on the motion of the Chairman a vote of thanks was accorded to him.

"A NEW PROPELLER."

Paper by JOHANN SCHUTTE.

Abstract.

THE purpose of the paper was to put before those interested in shipbuilding matters a description of a new propeller of rather a novel design.

With regard to the ordinary type of screw propeller, no definite decision has, as yet, been arrived at as to the best form, nor whether it is advisable to have constant or variable pitch. Designers of propellers probably give more attention to the form of blade. It is well known that the portions of the blades adjoining the boss contribute little to the propelling power of the screw. The propeller in question is designed with the object of reducing those parts and is the invention of Graf von Westphalen, of Vienna. The inventor's work is based on ideas which will be best understood from his own statements in the following letter:—

"Vienna, 20th August, 1900.

"Dear Mr. Schütte,

"This propeller has been evolved by means of numerous trials of various forms suggested by the following considerations. Propeller blades of the usual form, and with constant pitch, have the greater part of their surface at angles of 45 degrees and over. Such portions are not very efficient as regards propulsion, as they tend to drive the water away from the centre; and the more so the larger the angle and the greater the speed of rotation. With a screw having its blades in one plane and fixed directly on the boss in the usual way a retarding action is set up, owing to the comparatively greater thickness of the blade at the root, such thickness being necessary for purposes of strength. This part of the blade (assuming the face to be a plane surface), not having the same pitch as the tip, must set up a resistance in proportion to its thickness. Various trials with a propeller having a plane surface have shown that the water is drawn in spirally towards the centre; therefore the blades should decrease in width from tip to root. The proposed propeller embodies this idea. The arms fixed to the boss join the blades at the centre of gravity of hydraulic pressure. This construction allows the water free access

to each part of the blade and thus prevents a vacuum from forming, the consequence being that the propeller works evenly and free from vibration. As the radiating arms revolve in the same direction as the water in which they work they experience very little resistance.

I am, yours sincerely,

(Signed) Rudolph Graf von Westphalen zu Furstenberg."

A series of experiments was carried out with models of the new propeller in the North German Lloyd Company's tank at Bremerhaven, principally with the object of determining the most suitable shape of blade.

Of the various forms tried, the best results were obtained with a kite-shaped blade whose greatest width, which occurs at a distance of 72 per cent. of the propeller radius measured from the shaft centre-line, equals 0.3 of its length. From the widest part inwards the blade tapers down to and terminates at a point a short distance from the axis. All parts of the blade make the same angle—36 degrees with an athwart-ship plane; so that the pitch increases uniformly from the centre outwards. The arms which carry the blades are inclined to the shaft at an angle of 52 degrees, thus throwing the vertical plane containing the centre-lines of the blade-faces a definite distance abaft the boss.

As a result of the model experiments the North German Lloyd Company had the propellers of their T.S.S. "Seeadler" replaced by a set of the Westphalen design.

The dimensions of the "Seeadler" are:—Length between perpendiculars = 164.00 feet; extreme breadth = 26.24 feet; draught = 11.25 feet; displacement = 722 tons; wetted surface = 5575 square feet.

Original propellers:—Diameter = 9.18 feet; pitch = 13.61 feet; surface (4 blades) = 36.6 square feet.

Westphalen propellers:—Diameter = 9.18 feet; pitch (measured at "centre of gravity of hydraulic pressure") = 15.07 feet; surface (3 blades) = 15.5 square feet.

Trial results:—

	With Old Propeller.	With New Propeller.
Revolutions	107	99
Speed	12.3 knots.	12.3 knots.
Slip	14.0 p. cent.	16.6 p. cent.
I.H.P.	910	850

Besides figures and diagrams illustrating the design and geometry of the propeller, the paper included a curve of E.H.P. for the

"Seeadler" at the given displacement (the E.H.P. at 12.3 knots = 420) and a diagram showing the vibrations experienced in the engine room at practically the same revolutions with the old and new propellers respectively. The curves indicate a marked reduction of vibrational disturbance in the latter case.

Col. G. Rota, Mr. R. T. Napier, and Mr. C. J. Davidson took part in the Discussion; and the author replied.

On the motion of the Chairman a vote of thanks was accorded to the author.

The proceedings of the Section were brought to a close by a vote of thanks to the Chairman, proposed by Mr. R. T. Napier and seconded by Mr. J. M. Adams, to which Col. John Scott, C.B., responded.

SUMMARY OF PROCEEDINGS

OF

Section V.—Iron and Steel.*

TUESDAY, 3rd SEPTEMBER, 1901.

Mr. William Whitwell, Chairman, in the Chair.

PRESIDENTIAL ADDRESS.

This is the third time that the Iron and Steel Institute has been privileged to enjoy the hospitality of the City of Glasgow. Remembering the great benefits derived from the previous visits in 1872 and 1885, the members have been looking forward with satisfaction to the Institute's third meeting in Glasgow. Scotland had always held a pre-eminent position in the metallurgy of iron; and to Glasgow we owe the introduction of the first blowing cylinders at Carron Ironworks, which some of us hope to visit, the development of the mining of blackband iron ore, and James Beaumont Neilson's invention of the hot blast, one of the most important in the annals of metallurgy, well worthy of being ranked with those of Henry Cort and Henry Bessemer. It was at Carron that James Watt erected his first steam-engine, the patent for which was secured in 1769. It is especially pleasant to us that this meeting is held, by kind permission of the University Court, in the magnificent buildings of this ancient University, which for 450 years has been unflagging in its endeavours to benefit the world by scientific research. Glasgow University discovered James Watt, and appointed him their mathematical instrument maker. Glasgow University was the first University to found an engineering school and professorship of engineering. It was the first University to have a chemical teaching laboratory for students, and it was here that the first physical laboratory for the instruction of students in experimental

* The full Proceedings of Section V. form Volume LX., 1901, of the Journal of the Iron and Steel Institute, published by The Iron and Steel Institute, 28 Victoria Street, London, S.W. Price 16s.

work was established. In short, our debt to Glasgow University can with difficulty be estimated. Long may it pursue its career of useful work. *Vivat, crescat, floreat!*

Special interest attaches to this meeting, inasmuch as for the first time in the history of the Iron and Steel Institute we meet in conjunction with the Institution of Civil Engineers, the Institution of Mechanical Engineers, the Institution of Naval Architects, the Institution of Mining Engineers, the Institution of Electrical Engineers, the Institution of Gas Engineers, and the Incorporated Association of Municipal Engineers, forming one great International Engineering Congress. Once in our history we held a joint meeting in the United States with the American Institution of Mining Engineers and our German sister society, and the benefits derived were far-reaching. Speaking of that meeting, one of my distinguished predecessors in this chair wisely said:—

"These expeditions, through which we meet eye to eye and voice to voice our friendly competitors, to discuss the interests and the scientific aspects of the industry which absorbs us, have been of great personal and national benefit. It is thus we learn how much has been accomplished by persistent and intelligent labour, how much remains to be achieved, and how, by free exchange of ideas and of production, friendly understanding is promoted and personal acquaintance built up."

Animated by this spirit, the Iron and Steel Institute has desired to participate in this great Congress for the advance of common interests, and with the aim of widening our field of investigation, of avoiding the duplication of work, and of extending the ever-increasing fund of technical knowledge. The bulk of the progress in applied science can be traced to the technical societies, and every branch of engineering and industry shows the beneficial results of co-operation by workers in the same field. Indeed, the homely saying I quoted in my address to you last May is applicable to technical societies—"It is a wise farmer who looks over his neighbour's fence!"

At the present time, when the close of a century coincides with the end of the Victorian era, attention is naturally turned to the achievements of the nineteenth century. Conspicuous among these has been the development of technical societies. Organisations have been created and are active in every profession and in all branches of industry, science, and art. The growth of such societies has been accompanied by a decrease in the use of secret methods of manufacture. Manufacturing supremacy is now decided by other factors, and it is impossible to over-estimate the importance of professional and business men assembling to interchange ideas, and contributing funds for the publications of Transactions for the advancement of industry.

The knowledge gained by practical experience recorded in the Transactions of a technical society soon finds its way into the text-books for the instruction of students that will presently take our places and carry on our work. The mass of matter published by such societies is vast, and increases year by year. The eight Societies taking part in the Congress published last year among them no less than 6805 pages, distributed as follows:—

	Pages.
Institution of Civil Engineers	1981
Institution of Mechanical Engineers	644
Iron and Steel Institute	1173
Institution of Naval Architects	305
Institution of Mining Engineers	1255
Institution of Electrical Engineers	975
Institution of Gas Engineers	219
Incorporated Association of Municipal Engineers	253
Total	6805

In this overwhelming mass of published matter there is a certain amount of overlapping that this Conference may tend to obviate in the future. Some of the papers, too, at first sight appear to be of little practical importance. This criticism has frequently been applied to many of the papers read before the Iron and Steel Institute. It must be remembered, however, that this has been from time immemorial the favourite objection to the work of pioneers of thought. In this age of specialisation it is peculiarly important that hypothesis and generalisation—the complementary factors in scientific progress—should not be lost sight of. Mr. Balfour in a recent address, summarising the changes that have occurred in the nineteenth century, gives as the dominant note the close connection between theoretical knowledge and its utilitarian application. This is a startling verification of the soundness of scientific methods and of their capacity of indefinite perfectibility. With the development of scientific research, hypothesis, and generalisations, the practical applications of science become multiplied with rapidity and give the student (to borrow a simile from a brilliant writer in the *Edinburgh Review*) a satisfaction similar to that which a child feels when he has reached the final stages of putting together a puzzle-map of which the first steps were tentative and slow. Everything at the last falls quickly into its place, he finds nothing missing, and the map is complete and fit for use; yet, accuracy—or even approximate accuracy—in the earlier stages was a more important and difficult step towards ultimate success.

The thirty thousand pages published by the Iron and Steel Institute since its inauguration in 1871 afford fruitful examples of the subsequent value of scientific researches, which, when first presented, were received with coolness and suspicion by many of our members and by the technical press. Numerous examples might be cited. For instance, the microscopic method of investigating the structure of steel, created by Sorby, Martens, Osmond, Howe, and Stead, has become an indispensable auxiliary to chemical analysis and physical tests in steelworks. The abstruse memoirs on the heat treatment of steel, and on pyrometry, have led to important practical applications, and the phase rule enunciated by the American professor, Gibbs, and applied by Sir William Roberts-Austen, Baron Jüptner, Le Chatelier, and Stansfield, will no doubt eventually prove of extreme value in eludicating some of the more intricate problems confronting the metallurgist.

In short, by its papers, its discussions, and its interchange of ideas, the Iron and Steel Institute has advanced the science and art of metallurgy. It has rendered services to the world by assisting its progress, and is, I venture to think, not unworthy to accept the welcome which the West of Scotland ironmasters and the University of Glasgow are now so generously giving to it.

"THE IRON AND STEEL INDUSTRIES OF THE WEST OF SCOTLAND."

I.—PIG IRON.

By Henry Bumby.

On the previous occasions on which the Iron and Steel Institute has honoured Glasgow with its presence, papers have been read dealing so fully with the early history of ironmaking in Scotland that I will not venture to occupy your time by repeating what has already been so ably dealt with. I have, therefore, only added as an appendix (Table I.) a table of some of the more notable dates in the history of Scotch ironmaking, in the hope that others may be able to supply those which I have been unable to obtain.

Your previous visits to Glasgow, in 1872 and 1885, have practically coincided with the general introduction of radical changes in the Scotch pig iron industry.

When you first visited Scotland in 1872, the Scotch ironmasters were just beginning to utilise the hitherto "waste" gas for boilers and stoves, and to supplement their own native ores with ore from Spain, and you were told in the descriptive paper read at that meeting that "(at Coltness) . . . it is now finally resolved to go in for economical production by an application of the bell and cone to at least two of the blast furnaces." Whilst it was also told, as a remarkable fact, that at one works they had succeeded in making hæmatite pig entirely from Spanish ore. When you were here in 1885, the persistent efforts of Mr. M'Cosh and his partners to utilise the tar and ammonia contained in the furnace gas had just been crowned with success, and, encouraged by their example, several other works had begun to put down by-product plants, some of them of very remarkable design. Your *Journal* for that year contains descriptions of most of these plants, and most of us can remember the very great interest excited throughout the iron trade at the time, and the rather wild talk about pig iron "becoming an unimportant by-product," etc.

In the sixteen years which have elapsed since the last visit of the Iron and Steel Institute, there have been no such radical changes as marked the earlier periods. The period has been chiefly marked by the gradual increase in the proportion of steel-making pig, and by the improvement and extension of the works for recovering by-products from the gas which were commenced in the early eighties.

MATERIALS.

Coal.—The blast furnaces of Lanarkshire and Ayrshire have now been at regular work for over a century, and during three-quarters of that time they have worked mainly on the coal from two or three not exceptionally thick seams; add to this that until the last fifteen or twenty years both mining and smelting were conducted in the most wasteful manner, and it will be no cause for surprise that the best splint coals are showing signs of exhaustion.* Mining engineers have variously estimated the time for the exhaustion of the good splint coals of Lanarkshire at from ten to twenty years, and already the scarcity is making itself felt by those works which depend on the open market for their fuel supplies. To meet this scarcity of splint coal, some works are endeavouring to use in its place the softer semi-splint coals, with results which, so far, do not conduce to the comfort of their furnace managers. A more promising plan has been tried by one large firm, who coke the coal from the lower seams in very fine by-product ovens, and use a small proportion of coke with each barrow of coal.

With the exception of two firms who use from 10 to 25 per cent. coke, all the Scotch furnaces now work with raw coal.

Blackband.—The Lanarkshire blackband, which was discovered in 1801, has in 1901 been practically exhausted, as there are now no pits in the Lanarkshire coalfield working it as a principal product, though a small quantity of a thin blackband is raised with the gas coal at one or two pits. Some blackband of excellent quality is, however, still raised in Fife and Midlothian for smelting in the Lanarkshire furnaces, whilst the somewhat leaner blackbands of Ayrshire are still fairly plentiful.

Clayband.—From somewhat different causes the use of clayband ores has also declined greatly, and these are now but little worked, except in cases where they can be worked with a coal seam. The greatly increased cost of mining labour is partly responsible for this, whilst the greater attention paid to sampling and chemical analysis since hæmatite smelting became general has shown the necessity of abandoning many places working poor ores.

Other Ores.—So far as I can learn, no iron ore is at present worked in Scotland except the bedded claybands and blackbands of the carboniferous system, though several small vein deposits of hæmatite are know to exist in the older rocks, and comparatively small quantities have been worked from time to time; consequently the importation of foreign ores, which was almost

* G. A. Mitchell, Presidential Address to Mining Institute of Scotland, 1894. J. A. Longden, Presidential Address, Institution of Mining Engineers, London, 1899.

unknown twenty years ago, has been steadily growing year by year, from 42,471 tons in 1879 to 1,403,889 in 1899, the last year for which the Government statistics are as yet issued. With this new state of affairs, however, Scotch ironmasters have not abandoned their traditional policy of controlling their raw materials, and three of the largest firms now own or control mines in Spain which are believed to be capable of supplying their requirements of hæmatite for many years to come.

Preparation of Ores.—The extreme difficulty of maintaining regular working of furnaces supplied with soft coal and small and inferior ores has of late years caused considerable attention to be given to the briquetting of small ores. Several years ago Mr. G. Fisher, then manager of the Shotts Works, devised and patented a plant for working up the small dust from blackband into briquettes for the furnace, a little yellow clay being used as the agglomerant, and this is still working successfully. Since then several plants have been put down for the manufacture of briquettes from purple ores, clay or Irish aluminous ore being added as agglomerant. In the present year the Coltness Company have put up a large plant for screening the small ores from the Alquife mines, of which they are the principal owners, and moulding the finest smalls into briquettes, the machine used being a modification of the well-known Yeadon coal briquette machine, suitably strengthened.

Blast Furnace Equipment and Practice.—At the present time there is a greater uniformity in both dimensions and output of the furnaces at different works in Scotland than in any other district. In 1872 the average make per furnace per week was 165 tons, with a consumption of 2.95 tons of coal per ton of pig. In 1884 the production had increased to 200 tons, and the coal been reduced to 2.20 tons. In 1899 the production had increased to 270 tons, and the coal consumption decreased to 1.83 tons. Last year the average weekly production had decreased to 265 tons. The coal consumed per ton is not yet officially published, but will show a fractional increase—poorer results due entirely to the inferior quality of coal and ores used.*

To those accustomed to the hard driving of some recently constructed coke furnaces these makes will appear extremely small; it should not, however, be too hastily concluded that the proprietors and their managers are ignorant of their business. A furnace working on splint coal has to combine in itself a coke oven and a blast-furnace, and if it is driven so fast that any of the coal reaches the zone of fusion without having its 35 or 40 per

* "Thirty-sixth Annual Report, Alkali, etc., Acts, p. 170; also, "Thirty-seventh Report," p. 138.

cent. of water and volatile hydrocarbons expelled, the temperature there is so reduced as to completely disorganise the working. An obvious remedy would appear to be an increase in the height of the furnaces, and this was tried, and gave very good results so long as uniformly hard coal was used; but with an admixture of softer coals the crushing was too great, and many of the heightened furnaces have now been reduced to a height of 60 to 65 feet, which is the average height in Scotland. Of the many attempts made in the last few years to increase the rapidity of driving, one of the most encouraging was recently made at Clyde Ironworks, about which Mr. T. B. Rogerson writes me as follows:—"I cannot say much about our hard driving at Clyde, as we were on too short a time to make much comment; but this I can say, that we blew one furnace for three weeks with 8½ lbs. blast, and made about 90 tons a day of good iron. We had to stop this hard driving because of scarcity of water, and our stove power not being sufficient for all furnaces, but intend at some future date to again go on with it. We used nothing but splint coal during this trial."

As almost all the Scotch works are now equipped with by-product plants, the manager has to work with one eye on this department, and anything which tends to produce irregular driving in the furnace is very quickly reflected in the returns from the chemical department.

In one respect—the value of an increased number of tuyeres—Scotch practice has anticipated the conclusions of modern designers. For many years past eight or nine tuyeres have been the rule in Scotland, and in the last few years several have been built with twelve.

All the works in Scotland are now fitted with a full equipment of firebrick stoves, and fairly high temperatures (1200° to 1400° F.) are the rule. The stove which has found most favour is the Ford and Moncur—nine or ten out of the sixteen working plants in Scotland being fitted with this type, and some of the stoves have now been at work over ten years without any repairs other than the renewal of hot-blast valves.

With the comparatively small makes in vogue there has been no opening for blowing engines or charging machinery of the American type, but pig lifting and breaking machinery has been introduced at Messrs. Dixon's two works, Govan and Calder, and is giving complete satisfaction.

By-Products.

In 1885 the recovery of tar and ammonia from the blast-furnace was an infant industry just emerging from the region of small scale experiment. At the present time, with one exception, every works in Scotland either has a complete by-product plant or is erecting one, and all the earlier plants have been considerably enlarged and improved. In all the recent improvements the changes have been in the direction of simplicity of construction and safety in working; the size of the gas tubing has been increased ,and obstructions in the shape of sharp bends, etc., have as far as possible been avoided. The water coolers and high scrubber towers of the earlier plants have been replaced by the tar washer and horizontal liquor washer, which gives an almost complete abstraction of ammonia. They require little attention to keep them in perfect working order for years. They have the further advantage of holding only small quantities of gas in each compartment, so that the danger of a serious gas explosion is entirely eliminated. In designing these improvements, no one has done more than Mr. A. Gillespie, of Glasgow, and the three by-product works recently erected to his designs are admittedly the "show" plants of the country. As an example of the newest work in this direction, the following brief description of the new ammonia works at the Summerlee and Mossend Company at Coatbridge, for which I am indebted to Mr. Gillespie, will be of interest:—

Summerlee New Ammonia Plant.—"The Summerlee plant consists of seven furnaces, of which five or six are usually in blast at once. The gas from all the furnaces, having a temperature of 300 deg. Fah., or a little over, is first taken by a tube of 9 feet diameter to the tar washer (or primary washer), a horizontal vessel 64 feet long and 16 feet wide, in which the gas is split up and made to pass in thin streams under diaphragm plates sealed in tar. The hot gases are there brought into intimate contact with the tar; the operation is twice repeated in the vessel to ensure complete contact, with the result that the temperature is reduced by about 130 deg. Fah., and the heavier tars contained in the gas are entangled and thrown down, flowing slowly along the sloping bottom of the washer to the regulating valve, where they are automatically run off to the stock tank.

"The tar fed into the tar washer is the lighter tar from the liquor washer and condensers, containing a large excess of entangled water and gas; by the same operation these are expelled and the tar heated and prepared for distillation in the tar stills.

"The partially cooled gases pass from the tar washer to the air condensers, where they are again split up and pass into twelve boxes leading into a series of 20-inch vertical tubes having a total length of about 4½ miles. In passing through these the temperature of the gases is brought down to about that of the atmosphere, and they are in a fit state for the complete recovery of the ammonia in the form of liquor. The tar washer and condensers are placed on the suction side of the exhauster, and the first and second liquor washers on the discharge side.

"From the condensers the gas passes into the exhausters, of which there are three sets, of the horizontal cylinder type, each actuated by a pair of steam cylinders 18 inches diameter by 4 feet 6 inches stroke. The two gas cylinders are 6 feet diameter by the same stroke, each pair of exhausters being capable of passing 915,000 cubic feet of gas per hour at thirty revolutions per minute, or in all about $2\frac{3}{4}$ million cubic feet per hour.

"The two liquor washers are horizontal, 60 feet long by 12 feet 6 inches wide, in each of which the gas is repeatedly split up and impelled under diaphragms sealed in liquor, the first washer being fed with weak ammonia liquor, and the second with a small quantity of pure water.

"The products recovered in the condensers and the liquor washers pass into specially constructed separators, where, by the difference in specific gravity, the heavy and light frothy tars are each separated from the ammonia liquor. The washed gases are returned fit for use in the furnace stoves, steam boilers, etc., etc. The tar is dealt with in several tar stills, the oil distilled, graded, and separated, and the pitch run out in bulk or in blocks.

"The sulphate plant is capable of manufacturing forty tons of sulphate of ammonia per week, and the whole plant is arranged as far as possible to work automatically."

The amount of sulphate of ammonia recovered at the different works varies from 20 to 25 lbs. per ton of coal used in the furnaces, and the pitch and oil from 150 to 200 lbs.—the variations depending largely on the nature of the coal used, as the amount now lost in the gas at any of the works is extremely small.

Other By-Products.—Whilst our attention has been given to the recovery of tar and ammonia, the possibility of utilising other by-products of the blast furnace has not been entirely overlooked. The suitability of the washed gas for gas engines was demonstrated by the working of the gas engine at Wishaw—the pioneer of its class—with the history of which most of you will be familiar. That it has not as yet been followed by others is largely due to the fact that all the power and most of the heating required about the furnaces is already provided by the gas. For example, at one works, in addition to heating the blast furnace stoves and providing steam for the whole works, the gas serves to distil the tar and ammonia, heat the core-stoves for three large foundries, distil the coal for the gasworks supplying the village, etc., melt the steel in a steel foundry; and the surplus is being applied to burn the ore briquettes in a 12-chamber kiln.

Many attempts have been made to utilise the slag, but so far the demand shows little prospect of overtaking the supply. Much is used for railway ballast and for the foundations of roads, etc., and of late years considerable quantities have been used for making mortar and concrete, with good results. Slag bricks of excellent quality have been made experimentally, but, with the present low price of bricks made from colliery waste, there does not seem very much prospect of manufacture at a profit.

STATISTICS, ETC.

By the courtesy of Messrs. James Watson and Co., I am enabled to bring up to date the table of stocks, shipments, etc., given in Mr. Rowan's paper of 1885. From this it will be seen that the output of the Scotch furnaces has been practically stationary, whilst the shipments, and especially the foreign shipments, have decreased. Side by side with this, there has been a gradual change in the class of iron made. Up to 1885, the great bulk of the furnace output was foundry and forge iron; in 1890 the make of hæmatite had increased to 238,759 tons, against 498,307 tons of ordinary and basic; in 1899 the hematite amounted to 581,534 tons, compared with 572,486 tons of ordinary iron; and at present there are 43 furnaces making hæmatite, and only 36 working on foundry and forge iron. As the hæmatite made is almost entirely used in the Scotch steelworks, the decrease in pig iron shipments means chiefly that we are exporting finished steel and steel ships instead of crude pig iron.

In concluding this very hurried sketch of the present position of the Scotch pig iron industry, I have to thank the proprietors of the iron companies named, and Messrs. A. Gillespie and T. B. Rogerson, for permission to publish information so freely supplied to me.

TABLE I.

Some Notable Dates in the History of the Scotch Pig-Iron Trade.

About 1750	First charcoal blast-furnace in Argyleshire built.	
1760	Carron Ironworks started.	
1769	Watt and Roebuck erected a steam-engine near Carron.	
1779	Wilsowntown Works commenced.	Dismantled 1840-50.
1787	Omoa and Muirkirk Works commenced.	(Omoa now dismantled)
1788	Clyde Works commenced. (In this year there were eight furnaces at work in Scotland.)	
1792	Devon Works commenced (with furnaces cut out in the solid rock).	Stopped 1858.
,,	Glenbuck Works started.	Now stopped.
1801	Calder ,, ,,	
,,	Balgonie (Fife) Works started.	Now stopped.
1802	Shotts ,, ,,	
1805	Monkland ,, ,,	Now dismantled.
1828	Neilson hot-blast patent.	
1830	Gartsherrie Works started. (In this year there were twenty-seven furnaces in blast, and the year's production was 37,000 tons)	
1833	Dundyvan Works started.	Now dismantled.
1836	Coltness ,, ,,	
1837	Summerlee ,, ,,	
1838	Carnbroe ,, ,,	
1845	Gas collected and used at Dundyvan Works from a sixty-five feet furnace.	
1852	Iron ore calcined with gas at Coltness.	
1879-80	By-product works started at Gartsherrie.	
1896	Gas-engine works with furnace gas at Wishaw Ironworks.	

TABLE II.

Production of Sulphate of Ammonia from Scotch Blast-Furnaces (compiled from the Reports of the Chief Inspector of Alkali, &c., Works).

1883		about 400 Tons.
	(First reported separately in 1886.)	
1886		3,750
1887		4,849
1888		4,930
1889		5,645
1890	(Strike of Furnacemen)	4,564
1891		5,790
1892		10,500
1893	(Colliers' Strike)	8,333
1894		9,675
1895		14,188
1896		16,111
1897		17,379
1898		17,535
1899		17,563
1900		16,559

Table III.

Furnaces in Blast, Annual Make of Pig Iron, Stocks, Shipments, &c., 1875-1900.

	1875	1876	1877	1878	1879	1880	1881	1882	1883	1884	1885	1886	1887
Stock 1st January	96m	170m	363m	505m	679m	745m	739m	940m	836m	835m	821m	1050m	1183m
Shipments	543m	470m	445m	395m	555m	651m	563m	620m	623m	520m	430m	371m	407m
Make	1050m	1103m	982m	902m	932m	1049m	1176m	1126m	1129m	988m	1003m	936m	932m
Furnaces in blast, 1st January	121	113	116	86	91	100	124	105	112	103	93	91	75
Rail deliveries	73m	70m	60m	38m	23m	30m	28m	28m	27m	17m	15m	10m	4m
Consumption in Scotland	360m	370m	335m	294m	302m	384m	397m	585m	483m	468m	395m	422m	476m
Average prices	65/9	58/6	54/4	48/5	47/	54/6	49/2	49/4	46/9	42/1½	41/10	39/11	42/3
,, Furnaces in blast	117	116	103	90	88	106	116	108	110	95	90	83	80
,, Miners' Wages	5/	4/6	4/3	3/3	3/9	4/	4/	4/	4/6	4/6	4/	3/9	3/9
,, Bank of England rate of discount	3¼	2½	3	3¾	2½	2¾	3½	4	3½	3	3	3	3¼ per cent.

	1888	1889	1890*	1891*	1892	1893†	1894†	1895	1896	1897	1898	1899	1900
Stock 1st January	1228m	1244m	1035m	613m	579m	443m	381m	358m	480m	508m	464m	390m	277m
Shipments	413m	431m	441m	299m	329m	293m	252m	309m	306m	278m	287m	306m	326m
Make	1028m	999m	798m	674m	977m	783m	655m	1096m	1180m	1187m	1190m	1166m	1153m
Furnaces in blast, 1st January	85	77	88	6	78	67	43	73	79	80	81	83	84
Rail deliveries	9m	13m	13m	14m	12m	6m	5m	4m	4m	4m	4m	5m	5m
Consumption in Scotland	588m	762m	766m	394m	771m	546m	420m	661m	841m	948m	972m	968m	964m
Average prices	39/11	47/9	49/6	47/2	41/10	42/6	42/8	44/5	46/10	45/4	47/2	63/9	69/4
,, Furnaces in blast	84	84	66	51	77	53	45	74	80	79·73	82	83	83·61
,, Miners' wages	4/	5/	5/6	6/6	5/3	5/	5/6	4/9	4/3	4/6	5/4	6/2	7/4
,, Bank of England rate of discount	3¼	3½	4½	3½	3	3	2⅛	2	2½	2⅝	3¼	3¾	4 per cent

* Make reduced by strike of furnacemen. † Make reduced by strike of colliers.

II.—MALLEABLE IRON.

By William Wylie.

The malleable or manufactured iron trade, which is sometimes spoken of as if it were becoming almost a thing of the past, has suffered less in Scotland than in most other districts. In the three principal producing districts in Britain there has been very little change during the last three years, due entirely to the activity in the trade that has existed during that time; but comparing the output of twenty years ago with last year, we find the production of puddled iron, as taken from the statistics of the British Iron Trade Association, to be as follows, so far as particulars have been supplied by manufacturers:—

	United Kingdom. Tons.	South Staffordshire. Tons.	Cleveland. Tons.	Scotland. Tons.	South Wales. Tons.
1882	2,841,534	660,326	852,199	210,300	213,179
1900	1,162,765	265,181	198,131	206,316	practically none.

So that now the total production is only 41 per cent., South Staffordshire 40 per cent., Cleveland 20 per cent. of what it was, while Scotland has almost remained stationary during the whole of that period.

The manufacture of malleable iron commenced in Scotland over 100 years ago at various small places, amongst them being Muirkirk Ironworks, erected in 1790, and which are still in existence; but up to the middle of last century the trade was limited, and not to be compared in extent with that of South Wales, South Staffordshire, or the North of England; from that time onwards, however, new plants were laid down in rapid succession till about the year 1875, when the trade had reached its maximum.

By this time several of the older plants had been long since cleared away, and several of the largest establishments, such as Dundyvan Ironworks, Monkland Ironworks, Govan Bar Ironworks, and, rather later, Glasgow Ironworks, St. Rollox, were dismantled, and others, as Blochairn, Mossend, Parkhead, etc., converted into steelworks. Within more recent years other places have been established, as Waverley, Dundyvan (new), Woodside, and Victoria Works (only two years ago), all in Coatbridge district, while the Globe Ironworks have been transferred from Coatbridge to Motherwell, and Coatbridge Works have been rebuilt on a new site; many others have also been entirely remodelled. With these additions and improvements on the existing plants, the productive capacity, as has already been remarked, has remained constant. At the present time there are employed in the manufacture of malleable iron in Scotland 22 firms, owning 25 works, consisting of 396 puddling furnaces, 38 scrap furnaces, 17 bar mills, 23 guide mills, 8 strip mills, 21 sheet mills, producing 325,000 tons per annum finished iron of all kinds (from particulars supplied by the manufacturers). All the works, with one or two exceptions, are situated in the Coatbridge and Motherwell districts of Lanarkshire.

No new process having been introduced in the manufacture of puddled iron, the fundamental principles are just the same as have been in operation for the last fifty years or more, so that the only means of lowering the costs in order to meet the keen competition of modern times is by adopting from time to time all the minor improvements in furnaces and machinery, whereby the waste of material and consumption of fuel is lessened, the output increased, and thus the best results are obtained from the plant, and the general wages and charges are reduced. In this respect the various works have not been slow in adopting any means which they considered would be a benefit to them in their respective branches.

A quarter of a century or so ago any one passing through an iron-producing district used to be struck with the long tongues of fire from the blast furnaces, and the intermittent flames emitted from the innumerable stalks of puddling and mill furnaces. Now all this is changed; the former have all closed tops, the gases being used to heat the stoves and for raising steam, and there are few stalk furnaces to be seen in malleable works. The country around is now dark in comparison, the only light being the flash from the opening doors or the glow from metal on pig beds and when being conveyed to hammer or rolls, the blast-furnaces even requiring to be lit by electricity.

Puddling furnaces are rather larger than formerly, working heavier heats and more per shift, and all have closed grates with forced blast underneath in order to consume smaller fuels, and have boilers attached to utilise the waste heat for steam raising. The same may be said of mill furnaces; most in this district are ordinary coal furnaces, with boilers overhead or at end; gas furnaces have not been widely adopted in iron mills here. By making these of larger capacity, and devoting every attention to their construction, also by using the best types of high-speed engines and improvements about the rolls, the output of mills has been largely increased during recent years, so that it is no uncommon occurrence to have 12-inch guide-mills heating in two furnaces and rolling 30 to 40 tons of iron piles per turn of twelve hours, which is quite equal to the best practice of any district even of our American cousins in the same class of work.

A very varied class of trade is conducted in the iron mills in the district, both as regards the qualities and descriptions of material produced.

Best Scotch iron commands a high reputation, and all qualities are manufactured, from the common unmarked bars for the export market to the highest grades that can be produced; and, situated as all the works are within a short distance from Glasgow and the Clyde shipyards, where there is a concentration of all the allied industries—shipbuilding, marine engineering, boiler making, locomotive building, pipe and general founding, machine tool and general engineering, and fence, bridge, and roof building—there is a steady and large outlet for all sizes and descriptions of bars, ship and boiler plates, hoops, sheets, and sectional iron of all kinds.

Coatbridge may also be said to be the chief seat in the kingdom of the welded tube industry, so that there and in and around Glasgow there is a large demand for strips and tube hoops.

As a metallurgical centre the Scotch ironworks are, therefore, most favourably situated, having the great natural advantage of being within easy access of a seaport, as well as being in the midst of a perfect hive of allied industries.

It may here be said that for many years the wages of the employees of the malleable iron trade in Scotland were regulated by the decisions of the Board of Conciliation and Arbitration in the North of England, and this arrangement proved satisfactory in so far that no serious dispute had occurred for many years; but by the desire of the operatives a local board was formed in 1897 on the same principles as that of the North of England and South Staffordshire Boards, and so far it has amply justified its existence.

The author is indebted to the statistics of the British Iron Trade Association for figures as to production, and to the various manufacturers for their particulars of furnaces and mills, etc.

III.—STEEL.

By Henry Archibald.

In glancing back over the history of the steel industry of Scotland, an industry which has long maintained a high position for the excellence of its manufactures, we find, as far back as the year 1857, experiments being conducted at Coats' Iron Works and by Messrs. William Dixon and Co. at Govan, with small Bessemer plants; at the latter place under the personal supervision of the inventor.

Neither of these trials seem to have been successful, probably due to the phosphorus in the Scotch pig-iron experimented with, and the adoption of the process was abandoned at that time; but in the year 1861 we find Messrs. Rowan and Co., of Glasgow, beginning operations with a small Bessemer plant consisting of two 3-ton converters, and using Cumberland iron.

This works was manufacturing steel from 1861 until 1875, when it was dismantled; but during that period Messrs. Rowan seem to have made steel of exceedingly good quality, though only in very limited quantities.

In the year 1873 the Steel Company of Scotland built at Hallside the first open-hearth plant in Scotland. There were three furnaces built, of 6 tons capacity, and we find this firm steadily increasing their plant year by year until, in 1877, they had fourteen furnaces, ten of 6 tons and four of 10 tons capacity, and an output of ingots of about 36,000 tons per annum.

In the year 1879-1880 we find other firms entering the field, Messrs. Beardmore at Parkhead, Messrs. Colville at Motherwell, and Neilson's at Mossend, and about this time the Steel Company of Scotland bought and equipped the Blochairn Works in Glasgow. Under these circumstances it is not surprising to find that the total number of steel furnaces had risen, at the end of the year 1880, to 73, and the production of steel ingots to 84,500 tons.

With the earlier firms increasing their steel melting plants, and new works being erected, the production of ingots steadily increased. In 1881 the output of open-hearth ingots is given at 166,200 tons per annum; in 1882, 213,000 tons; 1883, 222,000 tons; 1884, 213,887, and in 1885 it had risen to a total of 241,074 tons per annum.

With 1885, a new departure was made in the manufacture of steel in Scotland, Messrs. Merry and Cunningham having adopted the basic Bessemer Process. This firm erected, in conjunction with the blast furnace plant at Glengarnock, four 10-ton converters with bar mills, etc., and in the following year the Glasgow Iron Co. started a somewhat similar plant in close proximity to their blast furnaces at Wishaw.

The plant at Wishaw consisted of three 7-ton converters, bar mills, etc., the intention of both firms being to utilise the local clayband and blackband ore, and the large deposits of ironworks cinder for the production of basic pig iron, and to convert the iron into basic steel.

The plant at Glangarnock is still in operation, but the Wishaw plant (owing to the difficulty of obtaining suitable raw material for manufacture of basic pig-iron) was discontinued, and dismantled some years ago, the converters being replaced by open hearth furnaces smelting hæmatite pig iron.

In the earlier days of the open hearth process the idea of the originators was to manufacture steel rails, but owing to the great fall in the price, and the scarcity of orders for this material, the manufacturers were forced to look for fresh fields for the disposal of their steel; and about the year 1875 the manufacture of steel bars and castings was begun, and the first plate mill started at Hallside works in 1877.

The shipbuilders on the Clyde seem to have been quick to appreciate the new material placed to their hand, for about the year 1877 three steamers were built of open-hearth steel from the local works, and from this time on to the present the open-hearth steel industry of Scotland has been steadily on the increase.

In Scotland at the present time nine firms with ten works are engaged in the production of open-hearth steel plates and bars. One of these firms, the Glengarnock Iron and Steel Co., is also engaged in the manufacture of basic Bessemer steel as previously mentioned.

The undernoted are the works referred to:—

The Hallside Works of the Steel Co. of Scotland, at Newton, manufacturing bars of every description, forging ingots, is the largest producer of steel castings in Scotland.

The Blochairn Works of the same Company, at Glasgow. Their chief product is plates for ship and boiler work.

The Dalzell Steel Works of Messrs. David Colville and Sons, at Motherwell, who manufacture plates for every class of boiler and ship work, bars of every description, heavy ingots for forgings, steel rolls, castings, etc.

The Parkhead Forge of Messrs. William Beardmore, at Glasgow. This works is principally devoted to the manufacture of armour plate, ordnance, projectiles, forgings, etc.

The Lanarkshire Works of The Lanarkshire Steel Co., at Flemington, manufacturing steel bars, forging ingots, etc.

The Wishaw Steel Works of The Glasgow Iron and Steel Co., at Wishaw, makers of ship and boiler plate, and bars.

The Glengarnock Works of the Glengarnock Iron and Steel Co., Ltd., Ayrshire, producing bars, billets, and girders.

The Clydebridge Steel Works of The Clydebridge Steel Co., Cambuslang. This firm are makers of plates only.

The Clydesdale Works of Messrs. Stewart and Menzies, Ltd., Mossend. Plates and tube strips form their chief product.

The Mossend Works of Summerlee and Mossend Iron and Steel Co., Ltd., Mossend. Makers of plates only.

Calderbank Works. Makers of plates only.

In addition to these works, there are numerous smaller works equipped with open hearth-furnaces, and Bessemer converters, or using the crucible furnaces for the production of steel castings or tool steel.

The statistics for 1900 show that there were, last year, 115 open hearth furnaces in Scotland—114 acid and 1 basic.

Of the 114 acid furnaces, the average number in operation during the year was 89, 25 furnaces being idle, and the one basic furnace working.

The total output of ingots from these furnaces was 963,345 tons, 960,581 being acid steel, and 2764 being basic steel ingots.

The output of open-hearth steel plates, bars, etc., for the same period was:—Plates and angles, 360,589 tons; bars, etc., 199,359 tons; blooms and billets, 56,839 tons; giving a total of 616,787 tons of finished material.

With reference to the total of 963,345 tons of open hearth ingots for Scotland, there remains to be added the output of the numerous smaller works employed in the manufacture of castings, etc., which will bring the total output for Scotland up to little short of 1,000,000 tons of steel for 1900.

To those members who were present at the last meeting of the Iron and Steel Institute, at Glasgow, in the autumn of 1885, and who availed themselves of the opportunity of visiting the local steel works, the great developments which have taken place in method of manufacture and in the plant in use at the present day, will appeal most strongly.

In 1885, the largest smelting furnaces had only a capacity of about 15 to 20 tons, to-day we have steel furnaces with a capacity of 50 to 60 tons at work, with all the necessary appliances for handling such quantities of molten steel.

Though charging machinery in connection with the smelting furnaces has not been adopted at any of the works in this district, its absence has in no way hindered the Scotch works from competing successfully, as regards output, with works where these machines have been introduced, owing largely to the improved design of the newer furnaces, the better facilities for handling the raw materials, and the greatly improved condition, as regards ventilation, etc., under which the men are required to work. Some of these furnaces hold the record for output for Great Britain; 1100 tons of ingots per fortnight being no unusual output for a 50-ton furnace.

With the gradual adoption of the larger furnaces, and improved types of gas producers, a corresponding economy has been effected in the cost of manufacture of the ingot.

As with the melting furnaces, so the old condition of things has changed in the manipulation of the steel ingots.

With the increased demands made on the steel trade by the engineer, the shipbuilder, and the boilermaker, for heavier and larger plates and sections, the necessity for improved appliances for handling heavy material, rapidly and economically, has gradually altered much of the steel works rolling plant within the last ten or fifteen years.

The old coal-fired horizontal ingot heating furnace has given place almost exclusively to the vertical gas-fired regenerative furnace, with the necessary arrangement of cranes of various types for charging and drawing the ingots, but nowhere is the change so marked as in the method of bringing the ingot down to the form of a slab.

In 1888 the steam hammer was in universal use for this purpose, with its army of hammermen and assistants. To-day the hammer, in conjunction with the plate or bar mill, is a thing of the past; its place being taken by the modern cogging mill, with its few men but many mechanical appliances, with cradle, tilters, etc. all worked by hydraulic power, and capable, as in the case of one of our most recent and best equipped mills, of turning out 60 to 70 tons per hour, and of cogging down slabs for the heaviest plate required.

The heavy plates now required for the market necessitate the handling of correspondingly heavy slabs, and to deal with them in an efficient manner large hot slab shears capable of cutting slabs four or five feet broad by 14 inches thick, are now used.

In the Scotch works the reheating furnaces for the slabs are practically all horizontal gas fired regenerative furnaces, and already one works in this district has adopted the mechanical charging and cleaning machines, and alterations are being made in one of the other works to adopt mechanical charging and cleaning in connection with their slab heating furnaces.

With reference to the plate and bar mills mechanical appliances are largely supplementing manual labour. Live roller gearing, etc., has been almost universally adopted at all mills, and the adoption of these appliances has been followed by increased yields and a corresponding economy in the cost of production.

The mechanical appliances in connection with the handling of plates on the mill floor, at the shears, and on the loading bank, have been slower in coming, but a movement has been made within this last few years, and some of the works are equipped with electric or steam overhead cranes to facilitate the handling of the plates, and as many of the plates turned out from these works are two inches in thickness, and of considerable area, while others are over eleven feet in width, mechanical arrangements for handling these expeditiously have become most necessary.

As with the plate mills so with the bar mills, the improved appliances have considerably increased the output, and whereas, some years ago, it was necessary to reduce the ingot to a bloom, and then wash heat the bloom before rolling into the bar, the bars can now be rolled direct from the ingots without wash heating, an improvement which effects a considerable saving in time, fuel, and labour.

The steel trade of Scotland has on many occasions been the pioneer in matters connected with the manufacture of steel, or in adopting appliances connected therewith, so that it is not surprising to find many of the Scotch steel makers fully alive to the necessity of adopting every appliance or improvement whereby economy can be effected. Owing to the largely increased production of steel at home, and the keen competition in the foreign markets, by new and more advantageously placed competitors, it is only by keeping the plant up-to-date that a steel works can now hold its own in a time of industrial depression.

Since the year 1873 the steel trade of Scotland has been almost wholly an acid open hearth one, and its reputation for this class of material is world-wide, but with the changing conditions of the times, the high price of hæmatite ores, and consequent increased price of pig iron low in phosphorus, and with the other impurities within reasonable limits, the question of adapting the steel furnaces to the working of basic pig iron by one of the more recently devised furnaces will have to be faced if the steel industry of Scotland is going to hold in the future that place which it has held in the past in the world's steel industry.

A vote of thanks was accorded to the authors, and to Mr. Dixon who read summaries of the papers.

"THE NOMENCLATURE OF METALLOGRAPHY."

Preliminary Report by a Committee of the Iron and Steel Institute.

Abstract.

IN view of the fact that, with the development of metallography, the nomenclature is becoming more and more involved, the Council of the Iron and Steel Institute, at the instigation of Mr. J. E. Stead, appointed a Committee, consisting of Mr. William Whitwell, President (chairman), Mr. F. W. Harbord (Englefield Green), Mr. E. Heyn (Charlottenburg), Mr. T. W. Hogg (Newburn), Professor H. M. Howe (New York), Baron H. von Jüptner (Donawitz, Austria), Professor H. le Chatelier (Paris), Mr. Walter Rosenhain (Birmingham), Mr. E. H. Saniter (Middlesbrough), Dr. A. Stansfield (London), Mr. J. E. Stead (Middlesbrough), and Mr. Bennett H. Brough (Secretary), to consider the matter, and to ascertain whether it would be possible to take steps to make the terminology less complicated and more precise.

A glossary has been drawn up in the hope that it will tend to promote the unification of terms, the simplification of those used, and the elimination of many of them. It is hoped, too, that the glossary may be improved, before final publication in the "Journal of the Iron and Steel Institute," by suggestions from members interested in the matter. Such suggestions, whether additional terms or better definitions, are earnestly invited by the Committee. As far as possible, the exact equivalents in French and German have been added. This addition will, it is hoped, prove of great value to those who are in the habit of consulting Continental memoirs in the original. It will, at the same time, be of assistance to the editor of the great "International Technical Lexicon," now being prepared under the direction and at the cost of the Society of German Engineers, a society which, with its roll of 16,000 members, is the largest engineering society in the world. The Iron and Steel Institute has undertaken to co-operate as far as possible in this great work, and it is thought that in drawing up an authoritative glossary of the most recent branch of the metallurgy of iron, the Iron and Steel Institute will be rendering valuable aid. Based upon the microscopic examination of thin sections of minerals and rocks, observations were recorded in 1858 by Dr. H. C. Sorby, member of the Iron and Steel Institute, in a paper on the microscopic structure of crystals, indicating the origin of

minerals and rocks ("Quarterly Journal of the Geological Society," vol. xiv., p. 453), and in October, 1867, by the late Mr. David Forbes, member of Council and Foreign Secretary of the Iron and Steel Institute. These observations gave birth to the special science of petrography. In view of the fact that metallic bodies are analogous to rocks, the exact knowledge of metals called for the creation of a corresponding science of metallography, in which the pioneers were Dr. Sorby, whose publications go back to 1864, and Professor Martens, whose publications go back to 1878. In 1880 the use of the microscope was introduced at the Le Creusot works, and the investigations of Mr. F. Osmond and Mr. J. Werth were started, and have been continued since that time along the path indicated by Dr. Sorby. Metallography is cultivated to-day in the principal metallurgical countries. Starting from the scientific laboratory, it has been extended further and further into works laboratories, where it will undoubtedly become an indispensable auxiliary to chemical analysis and physical tests. In view of its close analogy to petrography and to the study of meteoric irons, metallography necessitates the use of similar technical terms, and consequently, wherever possible, the terms familiar to the mineralogist and geologist should be used in describing the structures of metals and alloys, and the coining of new words should be deprecated.

The report concludes with a long alphabetical list containing the more important terms used by authors of memoirs dealing with metallography.

The preliminary report was read by the Secretary, and written contributions to the Discussion were received from the following:—Baron H. von Jüptner, Mr. T. Vaughan Hughes, Dr. Hubert-Jansen, and Captain W. Tressider.

"VARIATIONS OF CARBON AND PHOSPHORUS IN STEEL BILLETS."

Paper by AXEL WAHLBERG.

Abstract.

It is well known to all metallurgists that, ever since the introduction of the Bessemer and open-hearth processes on an extensive scale, it has been impossible to obtain ingots of a perfectly homogeneous chemical composition, the want of homogeneity being due to the successive process of segregation which takes place in consequence of the gradual solidification of the molten mass within the moulds. This segregation occurs in two different ways. Under normal conditions, especially if the casting temperature has been moderate, the alloys of a higher fusing point solidify more rapidly; in other words, the exterior parts of the ingot, particularly towards the lower end, become poorer in carbon, silicon, manganese, phosphorus, etc., owing to the gradual concentration of the bulk of these matters inwards and upwards. The concentration is most pronounced in the very core of the upper half of the ingot. The final result thus exhibits a gradual change in the chemical composition. Again, in other cases, if the casting operation is performed at a very high temperature, and the moulds are of a somewhat large size, both of which circumstances are conducive to slow cooling, there frequently occur, in addition to a more strongly marked tendency to segregation, conglomerations of a chemical composition quite distinct from the surrounding material, and abnormally large in quantity. These conglomerations, which are generally more accentuated in the more highly carbonised descriptions of steel, often prove a serious drawback in cases where material is intended for manufacturing purposes, although such irregularities as may be due to the one or other process of segregation are, of course, much modified, or even practically done away with, during the subsequent further treatment of the steel, a result which is chiefly due to the frequent reheating of the material.

As a matter of course, every user of steel is always anxious to obtain a material which is as nearly as possible homogeneous with regard to its chemical composition. Consequently there always exists on the part of the producers a corresponding tendency to comply, as far as is reasonable, with the requirements of the users

in this regard. But in the course of time those requirements have constantly increased, until they have now become excessive. This result may be ascribed partly to modern progress, especially with regard to improved methods of production; partly, also, and perhaps chiefly, to the fault of the manufacturers themselves, who, owing to the keen, untiring competition of the present day, are occasionally induced to accept any conditions, however absurd, for the sole purpose of securing a contract. It was this undesirable state of things that gave the stimulus to undertake the research presently to be described, because certain incidents have occurred recently which are of a nature such as to imperil the soundness of the steel market. As an illustration of the absurd requirements occasionally demanded by the consumers, the following fact which recently occurred may be quoted. It was a case of contracting for the delivery of steel containing 0.60 per cent. of carbon. The customer insisted seriously on the insertion of a clause in the agreement, stipulating that any steel which might be found to contain above 0.62 per cent. or below 0.58 per cent. of carbon was liable to rejection. The absurdity of such a condition is quite obvious, since not only is the range of variation in carbon in almost every case likely to prove far wider, but even if it were successfully confined within these narrow limits, there is still the probability that different chemists would obtain different results. The risks incurred by the manufacturer would therefore be exceedingly great. Nevertheless, it seems that there are manufacturers who do not hesitate to accept such extravagant conditions, and as the risk seems imminent of creating most unfair precedents in favour of buyers, it is a matter of urgent necessity to check a practice of this kind, which may be attended with the most serious consequences, before it spreads more widely.

Fully aware of these facts, the Board of Directors of the "Jernkontoret," who have ever manifested a most lively interest in any question touching on the Swedish metallurgical production and markets, have decided to institute an investigation, and have already, with their customary munificence, granted an ample sum for this purpose. Moreover, being desirous of ventilating the matter more thoroughly, and of securing a more authoritative opinion on the whole question, the Board of Directors further decided to submit the results of the proposed researches to this meeting.

The author then proceeds to describe the selection of material and taking of samples, and gives in tabular form the analytical results. These show that there can be no doubt that any contracts of delivery specifying too narrow a margin as to the percentage of carbon and phosphorus are always to be considered as involving more or less serious risks.

It must not be forgotten, however, that the most conspicuous defects in homogeneity have here been met with in the cross section of the ingots, or between the outer surface and the axis, while, as is well known, these faults will be essentially modified, or even practically done away with, if the subsequent treatment is rendered sufficiently effective, with repeated heatings. It is also to be remembered that such possible irregularities do not invariably make themselves evident on testing, as, for instance, in the case of analysing steel rolled into 2-inch square bars, from which the samples have been taken only either by boring or filing across the material.

With regard to the diversity of chemical composition at the top and bottom of the ingots, this difference will remain unaltered, independently of any subsequent treatment, this being a factor always to be taken into account.

This investigation also shows that occasionally considerably differing analytical results are obtained by different analysts and at different laboratories, a circumstance never to be overlooked in any case of contracting for deliveries, until quite satisfactory analytical methods are duly recognised and established by international agreement.

The following members took part in the Discussion:—Mr. J. E. Stead, Mr. G. J. Snelus, Mr. Benjamin Talbot, Mr. L. N. Ledingham, and Mr. F. W. Paul.

The author then replied, and a vote of thanks was accorded to him.

The meeting was then adjourned.

WEDNESDAY, 4th SEPTEMBER, 1901.

Mr. WILLIAM WHITWELL, Chairman, in the Chair.

"THE CORRECT TREATMENT OF STEEL."

Paper by C. H. RIDSDALE.

Abstract.

THIS paper, which is one of considerable length, is divided into six sections. The following is a synopsis of the contents:—

SECTION I.

Preliminary Remarks.—Much has been learnt of late as to how certain conditions in steel are brought about, but the knowledge is not being widely used, probably because it is not clearly connected with practice.

Objects of the Paper.—The author tries to describe, in simple, practical terms, what is known. He also formulates certain views and asks for information and discussion as to the control exercised by the maker and the user, their responsibility, tests, and processes.

SECTION II.

The effect of Composition and Initial Treatment as compared with Subsequent Treatment.

(a) Considered generally, as to what is possible. The importance of composition apart from treatment has been overrated. Later treatment often outweighs composition and initial treatment, and the maker can do nothing to provide against this. Twist tests quoted show that rolling hardness outweighs 0.15 per cent. carbon, and 0.40 per cent. manganese, while the purest and best steel fails when treatment is unsuitable, and irregular or impure steel stands if the treatment is right. German and American steel runs up to 0.10 per cent. and 0.14 per cent. phosphorus, and sometimes the sulphur is high. Steel users should take as great pains to control treatment as the makers do to control composition.

(b) As to what is likely in the ordinary working up. Much steel is worked up by separate users, who do not care to trouble about properties of steel, but simply want to shape it with the least possible cost. This—the use of wrong quality for untried purposes, or by works using chiefly iron—indiscriminate treatment, and other causes, all tend to develop faults, often only in a small proportion,

but discrediting the whole; yet the user seldom thinks of irregularity in his treatment as the cause, but throws the onus on the maker.

SECTION III.

Can the maker do more than at present, and, on the other hand, is it worth the user's while to try what he can do?—The maker can supply the most suitable composition when informed what processes the steel must undergo, but any slight further degree of purity attainable, whilst adding to the cost of production, would not improve the quality nearly so much as the means ready to hand —viz., for the user to study the character of each steel, and treat it discriminately. The best treatment may be quite easy.

SECTION IV.

In this Section are discussed:—the condition of steel at different temperatures: the cooling of steel: steel molten to critical point: critical point: below red heat: blue heat—the state of minimum plasticity: below blue heat: the reheating of steel: changes in the grain and "cement," whilst reheating.

SECTION V.

This section considers samples of processes and treatment which steel must undergo, including:—treatment by the maker: rolling ingots: finishing temperature of material to be reheated before further treatment immaterial: rails: medium sections tend to finish right, heavy sections too hot, light sections too cold; these can be controlled somewhat by the rate of cooling: girders etc.—finishing temperatures dictated by tests required: plates—much the same: bars for cold shearing—these should be finished fairly hot, and not chilled in any way.

Treatment by the user:—rolling after reheating,—reheat as rapidly as practicable for the mass, but all through avoid "soaking" if there is any delay: avoid burning and over annealing: the best temperatures can only be ascertained by experiment.

The Forge:—forgings should be worked out while hot enough for work to penetrate the mass: strains through unequal or partial heating can be removed by reheating without work: drop forgings, which are often finished too hot, should be reheated to break up the grain.

The Blacksmith's Shop:—forgings and weldings—avoid putting a nice finish at low temperatures: parts heated to welding without work should be reheated: the use of flux is explained: this latter is most desirable: tubes,—these are difficult to avoid burning or overheating when making thin tubes.

Gas Cylinders and other welded goods:—if only the part heated to welding receives work, these should be reheated.

Plates:—strains set up while flanging,—to avoid these they should be finished fairly hot or annealed.

Sheets:—Blackplates and Tinplates,—annealing may be carried to excess: streaks, roughness, indentations—these are due to foreign substances rolled in: certain kinds are never due to the steel maker.

Strips for stamping and cold rolling should be finished fairly hot, or, better, annealed.

Strips for welding should be rolled at low temperatures.

Hoops:—these have a tendency to overheat when getting down to thin sections.

Wire Rods and Plain Wire:—avoid hardness by cooling slowly in masses, and avoid chilling locally by cold objects; the tendency is to draw through extra passes without annealing.

Galvanised Wire:—brittleness is sometimes induced, especially in the larger sizes.

Pickling Hardness:—this is due to hydrogen, and may be removed by heating: pickling blisters are distinctive from other kinds, which are essentially the fault of the steel makers, and not that of the steel.

Galvanising is generally recognised as tending to make articles brittle.

Cold Drawing or Rolling:—this has a very marked hardening effect, sometimes producing great brittleness. Material for this should be as soft as possible, preferably annealed.

Section VI.

The required standard tests are discussed, and a table is given showing the types of faults and their manifestations, by whom originated, their probable cause; and tests for identifying the causes.

The following members took part in the Discussion:—Mr. J. E. Stead, Mr. Andrew M'William, Mr. T. Vaughan Hughes and the Chairman.

The author replied, and a vote of thanks was accorded to him.

"COPPER AND IRON ALLOYS."

Paper by J. E. STEAD.

Abstract.

AFTER briefly reviewing the contradictory evidence in metallurgical text-books, and showing the need of further research on the subject, the author described the nature of his recent work, which may be briefly summarised as follows:—

1. That copper and iron alloy most readily by direct fusion in all proportions.

2. That they may be classed into three main sections:—

   (a) Alloys containing from traces to 2.73 per cent. iron and 97.2 per cent. copper.

   (b) Alloys containing from traces to about 8 per cent. copper and 91.5 per cent. iron.

   (c) Alloys intermediate between *a* and *b*.

The alloys of (*a*) and (*b*) sections are practically homogeneous, (*a*) consisting of copper with iron in solid solution, and (*b*) consisting of iron with copper in solid solution.

(*c*) The alloys of this section apparently contain saturated solid solutions, copper in iron, and iron in copper, separate from each other, but in micro-juxtaposition.

The evidence is conclusive that in solidifying the alloys of section (*c*), the portion first to fall out of solution is the iron containing copper in solid solution.

The author discusses the effect of carbon, and showed that in the alloys containing more than 7.5 per cent. copper, on heating to whiteness with charcoal, copper containing about 10 per cent. iron is thrown out of solution, and falls to the bottom, leaving a layer of carburised iron on the surface, containing about 7.5 per cent. copper. In conclusion, he points out that the conflicting evidence referred to in the paper was most probably due to the fact that some of the experimenters in the past had not taken the precaution to use iron free from carbon in their experiments. He did not consider that the alloys of copper and iron were of industrial value.

The Discussion was combined with that on the paper by Messrs. Stead and Wigham (see page 199).

A vote of thanks was accorded to the author.

"THE INFLUENCE OF COPPER ON STEEL FOR WIRE-MAKING."

Paper by J. E. STEAD and F. H. WIGHAM.

Abstract.

THE authors describe experiments on a series of steels with and without copper, prepared by dividing the finished steel in each series, when in a fluid state, into two parts, to one part of which copper was added. The amount of copper added to the steel varied between 0.46 per cent. and 2.00 per cent. Four of the series were made by the Bessemer process, and one by melting in a crucible, in Sheffield. The mechanical properties of the steels are given in tabular form, showing the tenacity, bending and other properties, after each pass through the draw plates. The conclusion the authors arrive at is that the copper in such large quantities as they experimented with does not improve the quality of the wire, but generally has a deteriorating influence, particularly in the presence of high carbon. The only apparently good property cupreous steel wire possesses is that it is not so readily corroded as the non-cupreous material. In conclusion, the authors point out that it is desirable that further experiments should be made with smaller quantities of copper than 0.5 per cent., to ascertain what quantity is admissable without disadvantage.

The Discussion on the two papers by Mr. Stead and Messrs. Stead and Wigham was opened by Mr. Samuel Lloyd, and continued by Mr. Thomas Turner, Mr. T. Vaughan Hughes, Mr. Axel Wahlberg, Mr. A. J. Atkinson, Mr. A. M'William, and Mr. Frank Hill (by correspondence).

The authors replied, and a vote of thanks was accorded to them.

"THE PRESENCE OF CALCIUM IN HIGH GRADE FERRO-SILICON."

Paper by G. WATSON GRAY.

Abstract.

HIGH grade ferro-alloys of late years, especially those produced in the electric furnace, have presented many interesting points to the metallurgical chemist, and, at the same time, some troublesome ones to the analyst. Having recently come across ferro-silicon containing calcium, and not having noticed this element recorded before in a ferro-alloy, the author submits this paper, so that its presence may be noted by users, and its good or ill effect on the steel observed.

He has, for some time past, noticed the presence of magnesium and aluminium in ferro-chromes, but calcium has been absent. The presence of magnesium and aluminium is not to be wondered at, seeing that chrome ores contain these elements in large amounts, and that the reduction of the chrome ore is brought about in the electric furnace. The same, to some extent, may be expected with ferro-silicon, as no doubt calcium compounds constitute a large proportion of the flux. High grade ferro-silicon containing only a very small percentage of calcium can be made in the electric furnace, and if the presence of a large percentage of calcium is objectionable, the makers will have to arrange accordingly. He is, however, inclined to think the calcium will be beneficial, but this is a matter for practical trial by the users.

While the calcium may be looked upon as a special feature of some makes of high grade ferro-silicon, many of the other impurities, such as chromium, nickel, tungsten, are purely accidental, resulting from the remains of previous charges of ferro-alloys not being completely removed from the furnace. Their estimation, however, cannot always be neglected.

The author gives analyses of ferro-silicons containing 0.79, 3.29, 7.12, 6.96, 14.40, and 2.32 per cent. of silicon; and describes a new method for conducting the analysis.

Mr. T. Vaughan Hughes took part in the Discussion, and the author replied.

A vote of thanks was accorded to the author.

"THE PROFITABLE UTILISATION OF POWER FROM BLAST-FURNACE GASES."

Paper by B. H. THWAITE.

Abstract.

THE author explains that the results of his researches into the subject of fuel waste in our iron and steel works, on which he contributed a paper to the Iron and Steel Institute in the year 1892, culminated in his invention of utilising the waste effluent gases of blast furnaces in internal combustion engines; and that this invention, he further explains, has made the blast furnace a source of power, rivalling even that from waterfalls. It is further demonstrated that, owing to the blast furnaces being generally located in the centres of industrial areas, this source possesses advantages for the production of electrical power, both for industrial uses and for transmission purposes, not possessed by the waterfalls. The author explains that one of the results following the use of blast furnace gas for the direct production of power in internal combustion engines, has been a marked progress in the mechanical perfection of power capacities, and the thermo-dynamic efficiency of such engines. As high an efficiency as 30 per cent. has been obtained, and one of 25 per cent. should always be obtainable, and the power capacity of these engines is now no more limited than that of the steam engine.

The author describes his new scheme for obtaining all the power possible from the blast furnace. This includes the recovery of the sensible heat that is otherwise lost in cooling the blast furnace gases, for heating the air to gasify common coal in producers, and also to support the combustion of the gases thus produced in hot blast stoves, instead of employing the dirty, but, when cleaned, ideal power gas effluent from the blast furnace. This latter gas is in the author's system entirely diverted for the production of power. The hot blast stove efficiency is due to the positive supply of air and gas under pressure, which makes the combustion independent of the vagaries of the chimney draught. The higher thermal value of coal producer gas when burnt in fire brick chambers ensures a higher temperature of the stoves, and this in addition to the higher thermal recuperative efficiency due to the absence of lime dust; all of which advantages secure an efficiency such as cannot be expected from the present system, and react beneficially on the furnace. The author enters into an explanation of the reasons why hot blast stoves are so thermally inefficient, because

of the effect of the lime dust deposited on the brick surfaces, lime having only one-fifth the thermal conductivity of a brick that is absolutely clean. In the new system, the brickwork of the stoves will always be in the best condition for conducting heat.

The power potential of a blast furnace, when the new system is applied, is estimated as being equal to an output electrically transformed as follows for a furnace having an output capacity of 100 tons per diem:—

	I.H.P.	Elec. H.P.	Kilowatts reduced by 25 per cent.
CASE A.			
All the thermal value of blast furnace gas except that required for steam blowing engines is utilised for developing power in internal combustion engines, the hot blast stoves being fired with producer gas	3253	2602	1456
CASE B.			
All the thermal value of blast furnace gas, including that required to develop the power for blowing, pumping, and hoisting purposes, is utilised for developing power in internal combustion engines, the hot blast stoves being fired with producer gas	5093	4074	2280

The following are the characteristics of the furnace having the foregoing power output potential:—

Air blast pressure, 10 lbs. = 0.67 atm.

Combustible percentage of effluent gas, 28 p.c. $\begin{cases} CO = 24 \text{ p.c.} \\ H = 2 \text{ p.c.} \\ CH_4 = 2 \text{ p.c.} \end{cases}$

Combustible percentage of inert gas, 72 per cent. $\begin{cases} N = 60 \text{ p.c.} \\ CO_2 = 12 \text{ p.c.} \end{cases}$

Ratio CO_2 to $CO = 1$ to 2.

Fuel consumption per ton of pig iron = 900 kilos.

The author demonstrates why the blast furnace gas is almost ideal for producing power; he further points out that, seeing this gas flows from the furnace to the gas engine, as does water to a turbine, the labour associate of the dangerous steam boiler is not required. It is calculated that it will be possible, when the new system is applied throughout the year of 8000 hours, to develop one kw. hour at a cost of 0.15d., so that there is a margin of a satisfactory profit for the ironmaster without destroying the exceptional cheapness of the power. The author's system, in which all the blast furnace gas is available for power production, also provides an auxiliary power producing plant, so that when the blast furnace is blown out for any reason, the gas from the producing plant is diverted through the cleaning plant to the gas engine, coke fuel being substituted for slack coal, so there is no interruption in the continuity of the power-producing operation.

The author described the various outlets for electrical power that could be generated by the new system, including that involved in satisfying the internal requirements of an iron and steel works, and also for providing the electric energy to permit the remarkable series of electro-chemical and electro-metallurgical industries to be profitably operated. He demonstrates the peculiar advantages possessed by an iron works for carrying on these industries. He instances the production of silicon and calcium carbides, and the production of the metals chrome, nickel, and aluminium, which are exceptionally suitable as associated industries for an iron works. The principal electro-chemical and electro-metallurgical processes that have been developed during these last few years are briefly explained. *Inter alia,* he points out that some of the new carbides may be employed in the steel converter in place of the alloys, ferro-manganese and spiegeleisen. The increasing use of metallic chrome, silicon, and other metals to alloy with iron or steel emphasises the importance of the association of the industries producing these metals with that of iron and steel making. The importance of the new power system, as a profit making auxiliary to that of iron making, is emphasised, and especially the fact that the blast furnace being situated in the centre of many of our staple industries, gives the British ironmaster an advantage for the sale of power or of the products from it.

The principal electrolytic processes are also described. It is explained that when the blast furnaces are located within ten miles of a salt deposit, it will be possible to produce economically the alkaline products, such as those of sodium, caustic, and potash, as well as the chlorates.

The new system of power production, according to the author, may, when fully developed, have an important bearing upon the question of our being able to withstand a fierce onslaught of competition from whatever quarter it may come.

Mr. Edward Theisen opened the Discussion, and the following members also took part:—Mr. T. Vaughan Hughes, Mr. A. W. Richards, Mr. A. Greiner. Written contributions were also received from Mr. F. W. Lürmann, Mr. Horace Allen and Mr. J. E. Dowson.

The author replied to the Discussion at the meeting and by correspondence.

A vote of thanks was accorded to the author.

"AN INVESTIGATION OF THE SPECTRA OF FLAMES AT DIFFERENT PERIODS DURING THE BASIC BESSEMER BLOW."

Paper by W. N. Hartley and Hugh Ramage.

Abstract.

The whole of this work is based upon several previous investigations by one of the authors, published in the Philosophical Transactions of the Royal Society for 1894, under the general title of "Flame Spectra at High Temperatures" (Hartley). Results having reference to the spectroscopic phenomena and thermo-chemistry of the acid Bessemer process, as studied at the Crewe works of the L. & N.W. Railway, have already been communicated to the Iron and Steel Institute. The present communication deals with the basic process as carried out at the North-Eastern Steel Works, Middlesbrough.

General Statement of Results.—Twenty-six plates were developed with 140 spectra upon them, taken at intervals of one minute's exposure throughout the different stages of the blow, by means of a spectrograph designed for this purpose, which has been already described in the "Journal of the Iron and Steel Institute." Photographs of the flames and fumes were secured by means of an Anschütz camera fitted with a Goertz lens. Observations were rendered difficult owing to the large quantity of lime dust blown into the air. The spectroscopic results are quite different from those previously obtained. First, the continuous spectrum was much stronger, and appeared from the commencement of the blow; secondly, the strong bands of manganese are absent or greatly reduced in number and intensity; thirdly, many lines and bands new to the Bessemer flame spectra were observed in addition to the spectra of the alkali metals, iron, and manganese. Thus rubidium, cæsium, calcium, copper, silver, and gallium have been identified. Very careful chemical analyses of the crude iron, the ores, limestone, lime, slags, flue dust, and the finished steel were made, and their constituent elements have been traced all through the process of manufacture. The bases were in each case separated and identified by spectroscopic examination.

While no indication was obtained of the amount of phosphorus

in the metal during the process of "blowing," some insight into the chemistry of the process has been obtained. The greatest interest, however, is attached to the knowledge it has given of flame spectra under variations of temperature, and of the wide distribution of many of the rarer elements in minute proportions in ores and common minerals.

Description of the "Blow" and "Over-blow" in the Basic Bessemer Process.—The converter is first charged with about two tons of lime in lumps, and then with twelve tons of fluid "mixer metal," a mixture of metal coming direct from the blast furnace, and molten pig iron from the cupolas. The blast is turned on, and the vessel rotated into a nearly vertical position.

The blow may be divided into three stages. The first stage ends when the flame drops, indicating that the carbon has been burnt. The second stage ends when the vessel is turned down for a sample of metal to be taken out and the slag poured off. More lime is then added, and the blow is continued for a few seconds longer to complete the removal of the phosphorus; this forms the third stage. The average duration of the first stage was 12 minutes 20 seconds, and of the second stage 5½ minutes.

The blow began with the expulsion of a large quantity of lime dust, which hid everything from view for a minute or two, and covered the instrument and observers. A flame was visible at the mouth of the converter as soon as the cloud of dust had cleared away; this had a yellowish or yellowish-red colour. The flame grew rapidly in length, and remained clear as in the acid process until it dropped, and the second stage began. In this stage the flame was very short, and a large quantity of fume was expelled from the vessel; the flame grew longer, and the quantity of the fume increased as the blow proceeded. A plate of spectra was usually taken by giving the same time of exposure to each spectrum of the series until the flame dropped; two further exposures were then made on the flame of the over-blow. The spectra increases in intensity as the blow proceeds in the first stage, and this can only result from a corresponding increase in the temperature of the bath of metal and of the flame.

By the interference of the light reflected from a large quantity of white dust and smoke, delicate detail was obtainable only by working in the evening when the sun was very low, or after it had set.

Considerable difficulty was experienced in the identification of some of the lines and bands. The comparatively small disperson in the less refrangible portion of the green and red rays caused lines and the sharp edges of bands to be almost indistinguishable on the strong continuous spectrum. In other cases, lines were present which had not been observed in any flame spectra before.

CONCLUSIONS.

1. *The phenomena of the "basic" Bessemer blow differ considerably from those of the "acid" process.*—First, a flame is visible from the commencement of blowing, or as soon as the cloud of lime dust has dispersed. The authors conclude that the immediate production of this flame is caused by carbonaceous matter in the lining of the vessel; that its luminosity is due partly to the volatilisation of the alkalies, and to the incandescence of lime dust carried out by the blast.

Secondly, volatilisation of metal occurs largely at an early period in the blow, and is due to the difference in composition of the metal blown, chiefly to the smaller quantity of silicon. There is practically no distinct period when siliceous slags are formed in the "basic" process, and metals are volatilised readily in the reducing atmosphere, rich in carbon monoxide.

Thirdly, a very large amount of fume is formed towards the close of the second period. This arises from the oxidation of metal and of phosphorus in the iron phosphide being productive of a high temperature, but little or no carbon remaining. The flame is comparatively short, and the metallic vapours carried up are burnt by the blast.

Fourthly, the "over-blow" is characterised by a very powerful illumination from what appears to be a brilliant yellow flame; a dense fume is produced at this time, composed of oxidised metallic vapours, chiefly iron. These particles are undoubtedly of very minute dimensions, as is proved by the fact that they scatter the light which falls on them, and the cloud casts a brown shadow, and, on a still day, ascends to a great height. The spectrum is continuous, but does not extend beyond wave-length 4000. This indicates that the source of light is at a comparatively low temperature, approaching that of a yellowish-white heat. Consequently, the light emanates from a torrent of very small particles, liquid or solid, at a yellowish-white heat. The flame can have but little reducing power at this stage, and this, together with its low temperature, accounts for the very feeble lines of lithium, sodium, potassium, and manganese seen in the photographs or by eye observations.

Fifthly, the spectra of flames from the first stage of the basic process differ from those of the acid process in several particulars. The manganese bands are relatively feeble, and lines of elements, not usually associated with Bessemer metal, are present. Both the charges of metal and of basic material contribute to these. Lithium, sodium, potassium, rubidium, and cæsium have been traced mainly to the lime; manganese, copper, silver, and gallium to the metal. Other metals, such as vanadium and titanium, are not in evidence, because they do not yield flame spectra; they, together with chromium, pass into the slag in an oxidised state.

2. *Differences in the Intensity of Metallic Lines.*—The intensity of the lines of any metal varies with the amount of the metal in the charge, but in some cases variations of intensity occur among the lines of one metal, as observed in the spectra photographed at Crewe in 1893; especially is this the case with some lines in the visible spectrum of iron. These variations are due to changes in temperature; as the temperature of the flame rises, some lines fade almost away, others become stronger. Such changes are more marked in the arc spectrum, and still more in the spark spectrum of iron. Lines of potassium and the edges of manganese bands are shown to have been intensified by the proximity of iron lines in some cases, but this is doubtless a result of low dispersion. The two violet rubidium lines nearly coincide with two lines of iron.

3. *A new line of Potassium with Variable Intensity.*—This line, wave-length approximately 4642, varies in intensity within somewhat wide limits. In a given flame its brilliancy is increased by diminishing the quantity of metallic vapour in the flame; this does not appear to depend altogether on the weakening of the continuous spectrum which accompanies the line spectrum of potassium; the experiments made with various salts of potassium show that it is probably due, in part at least, to the increased freedom of motion permitted to the molecules of the metal.

The paper was taken as read.

A vote of thanks was accorded to the authors.

"BRINELL'S METHOD OF DETERMINING HARDNESS AND OTHER PROPERTIES OF IRON AND STEEL."

PART II.

Paper by AXEL WAHLBERG.

Abstract.

IN the Swedish section of the metallurgical department at the Paris Exhibition were displayed in systematic arrangement some results of experiments and methods of procedure relating to the testing of material, which attracted special attention. The experiments were conducted by Mr. J. A. Brinell, and the expense was borne by the Fagersta Works. They resulted in the development of a new and original method for determining the hardness and, to a certain extent, the tensile and ductile properties of iron and steel. The method alluded to is to be fully worked out on the initiative of the "Jernkontoret," which has granted ample funds for the purpose of carrying out further investigations on an extensive scale in the laboratory for testing materials at the Royal Technical High School at Stockholm. Among the most important questions to be decided by these experiments is that of ascertaining the practical utility of this method for determining the tensile properties of any kind of iron or steel material. For the purpose of comparison the experiments will be made with various qualities of both Swedish and foreign steel, the former being obtained from six or seven different works in Sweden. Mr. Wahlberg's paper gives an account of the results already achieved by Brinell. Among the more comprehensive researches described is a very complete series of results dealing with hardness, determined on steel specimens representing 1500 different charges of acid open-hearth steel, of a widely varying chemical composition. Many of the experiments were intended especially to illustrate the influence of annealing and hardening, and these probably form the most extensive series of experiments that has ever been attempted for this purpose. In carrying out the tensile tests Brinell made use of thirteen different kinds of steel, of varying composition, each of which had been subjected to no less than 31 different modes of treatment. In a second series, which was carried out for the purpose of ascertaining what impact stress the material could withstand, the same 13 kinds together with two more, were used, each kind in this case having been treated in ten different ways. Lastly, his researches on the

formation of blow-holes in ingots deserve notice. The results in this instance were obtained by testing 871 different charges, without taking any account of the innumerable experiments extending over several years, which Brinell made preparatory to drawing up his programme on the definite lines by which the later results were obtained. The first part of the paper was published in the "Journal of the Iron and Steel Institute" (1901, No. I., pp. 243 to 298), and the present paper, covering forty pages, and illustrated by numerous plates, completes the work. Mr. Wahlberg expresses his regret that Mr. Brinell has been unable to find time to prepare a paper describing his own labours and their results.

The paper was taken as read.

A vote of thanks was accorded to the author.

"THE INTERNAL STRAINS OF IRON AND STEEL AND THEIR BEARING UPON FRACTURE."

Paper by ARTHUR WINGHAM.

Abstract.

THE object of this paper is to assist the elucidation of some of the mysteries attendant upon the physical behaviour of metals generally, and of iron and steel in particular, and to throw light upon the cause of the sudden and unexpected breakages of metal used for machinery and other purposes. Its reasonings are based upon the following facts and hypotheses:—That there are two kinds of equilibrium to which a metal attains, viz., chemical and physical; that the natural tendency of a complex metal is to assume its most simple forms of combination preferentially capable of existing at a given temperature; that its rapidity of cooling, even under the slowest conditions, is too great to allow this to reach finality; that the equilibrium is further repeatedly interfered with by changes of atmospheric and other conditions; that the adjustment to physical equilibrium tends to assist the adjustment to chemical equilibrium; that adjustment which is assisted by slightly raised temperatures, also, as a consequence, takes place in the cold; and that the eutectic is the medium through which the chemical or molecular change takes place, working, of course, in conjunction with the vibration of the molecules. The subject is of both scientific interest and of practical importance. It is of great practical importance in the case of so-called permanent structures, especially where those structures are heavy and subjected to vibration or to shock. In such cases the greatest change or depreciation will take place at the points of jarring contact. Consequently, a strong and tough structural steel, well within the mechanical limits of the specification to-day, may, in the course of a few years, develop some of the properties more generally associated with cast iron. The latest instance of this is the recent mishap to the Brooklyn Bridge. The trouble appears to have been caused by the fracture of the vertical suspension rods holding the traffic way to the cables. The rods, no doubt, had a plentiful margin of original strength to cover any excessive or heavy usage, and it is hardly likely that the fractures were caused by extra traffic alone. It is more probable that the repeated vibration and the release of internal pressure by

the persistent tensile strain have accelerated an excessive tendency of the metal to crystallise, and so reduced its tensile strength. Other suspension rods in the same structure are probably approaching the same end. Obviously the internal stability of modern structural steel is worthy of serious consideration, when the selection of the best metal in view of longevity might prevent the comparatively early breakdown of an important structure.

The paper was taken as read.

Written contributions to the Discussion were received from Mr. J. E. Stead and Mr. Walter Rosenhain.

The author replied.

The following votes of thanks were then proposed by the Chairman:—

To the University Court for their kindness in granting the use of the Lecture Hall for the purposes of the meeting; to the Chairman, Mr. William Beardmore; to the Vice-President, Mr. Archibald Colville; to the Honorary Secretary, Mr. James G. Jenkins; to the members of the Local Reception Committee for the arrangement they had made; to the proprietors and managers of the various works for the permission given to visit their establishments; to the Railway Companies; and to the committees of the various Clubs who had accorded privileges to the members.

Sir David Dale, Bart., seconded.

Mr. George Beard proposed a vote of thanks to the Chairman, and Mr. E. J. Ljunberg seconded.

The Chairman acknowledged briefly, and Proceedings of the Section terminated.

SUMMARY OF PROCEEDINGS

OF

Section VI.—Mining.*

TUESDAY, 3rd SEPTEMBER, 1901.

Sir William Thomas Lewis, Bart., in the Chair.

PRESIDENTIAL ADDRESS.

By Sir William Thomas Lewis, Bart.,
Retiring President of the Institution of Mining Engineers.

EXTRACTS.

"It is pleasant to be able to congratulate all those connected with coal-mining as to the continued satisfactory condition of the coal trade, and it is especially gratifying for me to record the continuation of what has been referred to in detail by some of my predecessors respecting the reduced risk in the conduct of coal-mining operations, which recent statistics show to have been reduced to less than one-fourth of what it was per 1,000,000 tons raised when I first entered the profession 50 years ago, the death rate being 4 lives per 1,000,000 tons of coal raised in 1900 as against 19 persons killed per 1,000,000 tons raised in 1851. This increased safety, as you are aware, has been brought about gradually by the introduction of machinery, by improved discipline and better management; and from time to time Acts of Parliament have been passed which were based upon the accumulated experience of those connected with mining throughout the kingdom; but with all the improvements in mechanical appliances and in ventilation, as well as in the various protective arrangements carried out daily, I may say hourly, by the army of officials connected with collieries all over the kingdom, coal-mining is still, unfortunately, attended with risk, although the occupation as a whole ranks as particularly healthy as compared with other trades. The cause of almost one half of the accidents in coal-mines, that is, falls of roofs and sides, has of late had special

* The full Proceedings of Section VI., being part of Volume XXII., 1901, of the Transactions of the Institution of Mining Engineers, are published by the Institution of Mining Engineers, Neville Hall, Newcastle-upon-Tyne, price £1 1s. post free.

attention, and I look forward with confidence to a reduction in the number of such accidents in the districts where bad roofs prevail by additional care on the part of the miners in propping and timbering, and also by an extension of the use of improved lights for the workmen."

"Those who have means of reference will find that in addition to the greater immunity from accidents our miners now also enjoy much better pay for the same amount of work; so that, on the average comparing present operations with those of a similar kind 40 years ago, there has been a permanent increase in the labour cost of coal-getting of at least 20 per cent.—leaving entirely out of the calculation the recent prosperous times in the coal trade."

"Of our total coal-output no less than 58,405,000 tons were exported, being 3,000,000 tons higher than any previous year's coal-export—the following being our principal customers:—France, 7,541,000 tons; Germany, 6,099,000 tons; Italy, 4,947,000 tons; Sweden, 3,035,000 tons; Belgium, 1,213,000 tons; Russia, 2,000,000 tons; and Spain, 1,500,000 tons.

The United States coal-export in 1900 amounted to 7,551,850 tons, which was double their coal-exports in 1897; and as a large number of new collieries have been recently opened and equipped with the best mechanical appliances, it is fully expected in order to keep the mines regularly at work there will be a further increased output in the States, which will be thrown on the export markets."

"In connection with the preservation of our export trade it must not be forgotten how greatly the nation benefits through the number of steamers employed in carrying the export coal; and by reason of many of the steamers thereby securing a round trip our manufacturers and others depending on imports are enabled to secure their supplies at much lower rates of freight than would otherwise have been possible.

Some of my predecessors in this chair have dwelt upon the important matter of the duration of our coal-resources, which has recently again been the subject of discussion. Of course the duration of our minerals depends first of all upon the probable yield of useful fuel from our several coal-fields, and next what our annual requirements, including exports, are likely to be in the future. So far I have been unable to discover, in the various calculations made as to the quantity of useful coal remaining in our coal-fields, to what extent it has been assumed the present wasteful mode of working in some of the fields may continue to be modified; and, on the other hand, whether the present wasteful mode of using coal in our steam engines and our manufactures is also assumed to continue. The modification of either of which would of course make a very material difference in the number of years that our usable coal will last.

With every desire to avoid anticipating the enquiry which has been indicated probable by a Royal Commission, and without attempting to follow the various eminent geologists and engineers, who have recently dealt with this subject, into their calculations as to the number of millions of tons of coal remaining unworked in the United Kingdom, which will, I have no doubt, be carefully gone into if the proposed commission is appointed, I think it useful to direct your special attention to some important points bearing upon the question of our mineral resources, namely:—

(1) The enormous waste there has been in the past, and continues at present in many places, in the working of the various seams of coal.

(2) The loss through such a number of seams of coal being left in the ground, owing to their quality, their thinness, or their proximity to more valuable seams, and their being depreciated by the working of the more valuable seams.

(3) The custom which prevails in many districts of lessees working out only the best or more profitable seams, without regard to the effect upon the thinner, inferior, or more expensive seams under the same properties; and also the loss through such great quantities of small coal being made in working, and the proportion of small coal left underground in many districts."

"With respect to seams left unworked through their thinness or their proximity to more valuable coal-seams, it is gratifying to record the very great change that has taken place throughout the kingdom, especially since the introduction of the long-wall system, as to the thickness of what is regarded as a workable seam of coal. I find from a paper read by the late Mr. G. C. Greenwell on the working of thin seams of coal by longwall and bord-and-pillar about 35 years ago, that in the more highly favoured coal-districts of the country seams of 2½ feet, or even more than that thickness, were at that time considered unworkable to a profit, and consequently left in the mine untouched; and Mr. Greenwell further stated that in the Newcastle Coalmeasures there were no fewer than 15 seams of coal under 2 feet 6 inches in thickness which were all considered unworkable, while at the same time in collieries under his management in the neighbourhood of Bath 3 seams were worked varying from 12 to 16 inches thick, and 4 seams varying from 2 feet to 2 feet 4 inches thick."

"With reference to the number of tons of coal unworked in our different coal-fields it is of course easy to calculate from the plans and sections of the seams proved, making the usual allowances for faults and loss in working; but, as I have endeavoured to indicate, the important question is, how many of the seams can be assumed to be workable to profit from time to time, and how much of the coal contained in the various seams can be usefully obtained. If the thin seams cannot now be worked, while we have superior coals in thick seams to mix with them, I fear that many of the thinner and the inferior coal-seams are much less likely to be profitably worked in the future, when they have to be worked in many cases either above or below abandoned workings, which may have subsided or be subject to water or any other causes, and when to some extent they will require to be won by deeper and more expensive collieries; the whole of which of course are elements of great uncertainty.

So much on the question of waste and loss that, in my opinion, can and should be modified so as to prolong our useful sources of supply; and then comes the question of our requirements as a nation, first for home consumption, and next for exportation and the maintenance of our commercial position. As to our own requirements there can be no doubt that great saving ought to, and I hope will, be effected, if not immediately, most certainly when our coal-output becomes more costly. It is of course dangerous to prophesy, as has been instanced by the estimates of so many of the eminent men who dealt with the subject in connection with the Royal Coal Commission of 1871, which subsequently were found inaccurate; but we may at all events reasonably assume that as our fuel becomes more costly further attempts will be made to continue improvements in the direction of realising a much nearer approach to the theoretical value of our coal, and thus secure further enormous economies.

"Were it not that our fuel had been so cheap until recent years many of the economies which have been introduced from time to time in our modern boilers, our best engines and manufacturing machines, and operations of various kinds, instead of being confined to modern works only would have been generally adopted by all steam users and manufacturers, and thereby a great saving of our fuel effected. With reference to a portion of this subject I may be pardoned for calling attention to the contents of a most valuable paper read at the last meeting of the Institution of Mechanical Engineers, at Barrow, by Mr. James M'Kechnie, wherein he sets forth the great improvements that have taken place in the boilers and engines of steamers during the last 30 years by improved boiler and heating arrangements, the adoption of higher steam pressure, the compounding of engines, and increased piston speed; which has resulted in the average consumption of fuel in steamers being reduced from 2.11 lbs. per H.P. per hour in 1872 to 1.83 lbs. per H.P. per hour in 1881, to 1.52 lbs. per H.P. per hour in 1891, and to 1.48 lbs. per H.P. per hour in 1901.

It is hardly necessary to point out that such an apparently small saving, if applied to all the boilers in the United Kingdom, as well as the steamers sailing under the British flag, would represent millions of tons per annum; and considering that even with these economical results we are far from enjoying one half of the economies which experts consider may still be made in the use of coal for steam purposes, and that we may confidently expect great advantages by the utilisation of inferior coals, by gas arrangements such as Mr. Mond's and others', by the extension of the utilisation of gas for manufacturing purposes, by the application of gas for the generation of electric power for lighting and heating, by the application of our water supply for the generation of electric power, and also by the application of liquid fuel for various purposes—enormous savings of fuel could be secured which would greatly reduce our consumption of coal. This, coupled with the husbanding of our coal resources by a substantial reduction of the waste I have previously referred to in the working of our coal-seams, would, in my opinion, extend the duration of our coal resources so as to provide for all our requirements and maintain our commercial position as a nation, while amply providing for the protection of our country, for a much longer term of years than any of the recent estimates I have seen on the subject."

On the motion of Mr. H. C. Peake, seconded by Mr. J. A. Longden, a vote of thanks was accorded to the Chairman for his address.

Thereafter the Chairman introduced Mr. James S. Dixon, the president of the Institution of Mining Engineers, who thereupon took the Chair.

Mr. Dixon acknowledged the honour which had fallen to him in being elected President of The Institution of Mining Engineers. In the course of a short address, he remarked upon the absence in Scotland of a centre for the teaching of the higher branches of the science and practice of mining, and announced his intention of giving a sum of £10,000 for the endowment of a lectureship in mining in the University of Glasgow. The Very Rev. Principal Story, on behalf of the University, gratefully acknowledged the gift.

Mr. JAMES S. DIXON in the Chair.

"THE OIL SHALE FIELDS OF THE LOTHIANS."

Paper by H. M. CADELL.

Abstract.

THE author first described generally the principal characteristics of the Scottish carboniferous system of the Lothians, which included the coal measures, millstone grit, carboniferous limestone, and lower carboniferous or calciferous sandstone series. The last and lowest of these divisions contained in its upper section the oil shale measures. The thickness of the calciferous sandstone series he estimated in round figures at 9000 feet, and the oil shale measures occupied the upper 3000 feet of this section. Oil shale was not necessarily confined to this geological horizon, but in Scotland all the oil was at present derived from seams comprised in it. The shale produced ammonia as well as oil, and the sulphate of ammonia was now one of the principal products without which shale could hardly be profitably worked. The shale seams were about six in number, and varied in thickness from two up to fifteen or more feet. The principal shales were known as the Raeburn Fields, Broxburn, Dunnet, and Pumpherston shales, but at some places these seams were divided into several parts, each of which was workable. Good shale produced 30 gallons of crude oil and 40 or 50 lbs. of sulphate of ammonia per ton. The shale fields were far from regular in form, and the whole area was much folded and faulted, and was at places invaded by large sheets of intrusive basalt. The author described in detail the geological features of the various shale fields worked by about ten different companies, with a total capital of nearly £2,000,000. The industry was an important one, and the author thought great credit was due to the Scottish companies for the inventive genius, perseverance, and pluck they had shown in carrying on the industry for many years, in face of the fierce competition from America and other places, where the oil spouted up ready made, and no great skill was required to win it from the soil. The principal shale fields were those of West Calder, Mid Calder, Pumpherston, Broxburn, Philpstown, Hopetoun, Dalmeny, Straiton, and Burntisland, but shale was not being worked at all these places. The author exhibited a geological map he had prepared, showing the probable geographical extent of the available shale measures, and illustrated the paper, which was a long one, by numerous vertical and horizontal sections across typical areas in West and Mid Lothian.

A vote of thanks was accorded to the author.

"THE CARBONIFEROUS LIMESTONE COAL-FIELDS OF WEST LOTHIAN."

Paper by H. M. CADELL.

Abstract.

THE carboniferous limestone series of Linlithgowshire (or West Lothian), immediately covering the oil shales, was about 2000 feet in thickness, and was marked by three upper limestone beds, and by two or more similar marine beds at the base, between which were found the coal measures of Bo'ness and the district at and to the south of Bathgate. The series was characterised by a great development of volcanic rocks, basalt, and tuffs, which were interstratified with the coal seams of Bo'ness and Bathgate. Between these localities the volcanic rocks were very thick, and occupied the position of the coals and non-volcanic strata. In the centre of the area, to the south of Linlithgow, there was a volcanic bank over 2000 feet thick, where no coal had apparently been formed; but to the north and south of this nucleus the trap rocks thinned away, and the coals began to increase. The Bo'ness coalfield contained more workable and generally better seams than the Bathgate field, and the author exhibited a series of vertical sections showing the relative proportion of coal-bearing and volcanic rock along the strip of carboniferous limestone ground extending for 12 miles southward from Bo'ness. He said he had often been asked to trace the Bo'ness coal seams into the Bathgate district, and state which seams in the one coalfield corresponded with those in the other. His answer in this paper was that there was really no connection between them, as the volcanic rocks had apparently produced a barrier in the carboniferous sea, on each side of which different strata were being laid down during most of the coal producing period. It was not till the upper limestones were deposited that the volcanic bank became sufficiently submerged for the sea to flow continuously across it, and permit of the uninterrupted deposit of sedimentary rocks.

Mr. J. G. Weeks, the Chairman, and Mr. James M'Murtrie took part in the Discussion, and the author replied.

A vote of thanks was accorded to the author.

"THE TARQUAH GOLD-FIELD, GOLD COAST, WEST AFRICA."

Paper by A. R. SAWYER.

Abstract.

THE Tarquah gold-field is situated in the Gold Coast colony. It is connected with the coast at Sekondi by a narrow gauge (3½ feet) railway. This railway, which is being constructed to Koomasi, is already open for traffic between the village of Tarquah (situated somewhere about the centre of the south-eastern edge of the gold-field) and Sekondi, a distance of 40 miles; and its course from Tarquah is as far as Cinnamon Bippo, a distance of about 7 or 8 miles along the south-eastern edge of the gold-field. There it leaves the south-eastern outcrops and cuts across country to the same outcrops, which have been shifted forward in a north-westerly direction. The railway passes on to these new outcrops about 17 miles from Tarquah, and continues along them to Aponsu, a distance of 40 miles from Tarquah.

The reefs in the Tarquah gold-field are undoubtedly conglomerates, occurring in a sandstone-and-quartzite formation. These rocks occur as fine and coarse grained, and in some cases so coarse-grained as to become grits. They often contain scattered pebbles. There is no doubt that these sandstones and grits become quartzitic in depth. These rocks differ in no wise from the same rocks on the Rand, except in the fact, which the reefs also share, that they contain a very large quantity of iron oxide, which mostly occurs in irregular thin bands or veins, giving the sandstone or quartzite a "striped" appearance.

The thickness of this sandstone-quartzite formation is not easily determined, owing to probable duplication and to scarcity of available outcrops. The writer estimates the thickness, however, at between 4000 and 8000 feet. Overlying this formation and conformable with it, occurs a thick slightly arenaceous clay-slate formation, containing a few thin, fine-grained sandstone beds. He found the clay slates about three miles from the Wassau mine, and these still continued where he left off his examination. At this point, the clay-slate formation had a dip of from 5 to 10 degrees, and dipped consequently at a slightly flatter angle than in the

south-western portion of the goldfield. This formation the writer estimated to be at least 1000 feet thick. In whatever direction the quartzites dip, these slates, which invariably accompany them, dip, owing to their conformability, in the same direction. They form a useful index of the position of the reefs, as will appear further on. These two intimately connected formations make up the gold-field, and although the slates are not auriferous, they certainly overlie the quartzites, with the conglomerate-reefs contained therein.

The enclosing formations are, so far as the writer can judge, mostly basic igneous rocks, and schists and slates derived from them. These rocks contain white auriferous quartz-reefs, like those at Preston and Crockerville, generally with a trend parallel to the prevailing trend of the conglomerate outcrops.

The gold-field has a tendency to a long synclinal shape trending about 40 degrees north-east. The continuity of the syncline south-westward is disturbed. Powerful dynamic forces have there thrown the sandstone-quartzite formation almost at right angles to the syncline.

With numerous comparatively small disturbances, the sandstone-quartzite formation forming the south-eastern edge of the syncline, which consequently dips in a north-westerly direction, extends as far as the neighbourhood of the village of Busumchi, a total distance from Tamsoo of about 20 miles. Here another powerful disturbance appears to have thrown the whole formation north-westward about four miles, as there the peculiarly striped quartzite formation appears strongly, with a strike parallel to that of the large syncline and a north-westerly dip.

The resemblance between the Witwatersrand and Tarquah synclines, with respect to the large disturbances occurring at either end, is striking. The Detchikroom disturbance corresponds to the large Witjpoorte fault and the Busumchi disturbance to the Boksburg fault, which throws the Moddersfontein series some miles to the north. Just as the Randfontein series there strike at right angles to the Rand, so here the Detchikroom disturbance strikes at right angles to the large Tarquah syncline.

The matrix of the reef consists invariably, near the surface, of sandstone composed of quartz-grains, white mica, and iron oxide, which becomes compact and quartzitic in depth. At the extreme ends of the syncline, namely at Teberibi and Tamsoo to the south-west, and near Busumchi to the north-east, the matrix is schistose. This characteristic is due to shearing, no doubt produced by the earth movements which prevailed during the occurrence of the great disturbances at each end of the known syncline. The pebbles vary in size up to 8 inches, and near the surface are invariably coated with white mica. They consist mostly of white quartz. Darker quartz-pebbles and dark indurated slate-pebbles also occur.

Patches of talc and red clay occur. The quartz pebbles are opaque, translucent and sugary or saccharoidal, in some cases being very friable. Under the microscope, the quartzites and conglomerates nearly all show evidence of strain and crushing from shearing.

Unlike the pebbles of the Rand banket, in which gold occurs very rarely if at all, the Tarquah conglomerate pebbles occasionally contain gold. The quartz-reefs from which they are derived must have been more or less auriferous, like some of the quartz-reefs now being worked in the neighbourhood of Prestea, and by the Ashanti Goldfields, Limited. The principal amount of gold occurs, however, like on the Rand, in the matrix.

The unaltered condition of the hæmatite both in the quartzites and conglomerates, down to the depth at which it has been found, is remarkable. It is not improbable that pyrites will be found to replace hæmatite in the matrix at a greater depth.

The dykes, in or about this gold-field, consist mostly of basic igneous rocks, but a few examples of intermediate igneous rocks occur. Dolerites and diabases are the only representatives of the basic igneous rocks. The few intermediate igneous rocks are diorite (the plutonic or deep-seated form) and andesite (porphyrite) the volcanic form, which usually occurs as a dyke.

The writer has not seen any granite either in or about this gold-field, nor has he seen any between Sekondi and Tarquah. Typical hornblende-biotite-gneiss occurs on the coast near Sekondi, and is quarried there for building purposes, but he has not seen any such rock in or about the Tarquah gold-field.

The writer stated in a paper on the Witwatersrand gold-field, read before the North Staffordshire Institute of Mining and Mechanical Engineers on October 4th, 1889, that "The length of their (bankets) extension, coupled with the steepness of their dip, justly suggested a continuation downwards for a considerable distance."* Just as on the Rand the length of outcrop indicated continuity in depth, so here the long known lengths of outcrop warrant the same conclusion. The view expressed in 1889 has been so splendidly confirmed on the Rand that he did not see how it could be otherwise here.

The rocks surrounding the Tarquah gold-field are mostly of basic igneous origin. At Prestea, a graphitic schist-layer occurs in close proximity to the quartz-reef. The Prestea reef is a bedded quartz-reef, and has a strike of north 48 degrees west with a dip 60 degrees to the north-east.

There is no question in the writer's mind as to the permanency of the conglomerate-beds in depth. They differ in thickness at

* Trans. Inst. Min. Eng., 1889, vol. x.

the different mines, but it may be broadly stated that these beds are considerably thicker at the south-western end of the syncline than at the north-eastern end, and that the thicker they are the lower the grade.

A vote of thanks was accorded to the author.

"BRICK-MAKING."

Paper by George L. Allen.

Abstract.

In making clay into bricks the only forces that can be used are natural crystallization and artificial cohesive attraction. The former process is best suited to clays naturally plastic, and the latter for dry clays; while a combination of the two may be satisfactorily employed in treating certain classes of raw material. These methods may be termed the plastic, the dry press, and the semi-plastic, and the manufacturer who wishes to found a successful business must satisfy himself at the beginning as to which method is most suitable for his material.

Plastic Clay Bricks.—In making plastic clay bricks, one very important matter is to see that the clay is well mixed at the face. The waggon which conveys the clay to the machinery should contain a regular admixture of the various stratas of the clay bed, as different sections usually require different treatment in drying and burning.

It is important that the physical or natural condition of the clay should be entirely broken up, and this should be accomplished, as far as possible, by first passing it through a mixing mill and rollers before it reaches the pug mill. The pug mill alone is too often relied upon for thoroughly mixing and shredding the clay. The duties of the pug mill are to consolidate the clay and press it through the die into a continuous column. This column should be thoroughly compact, free from lamination, and have a fine, polished surface, clean and unbroken at the corners. Several machine makers are now making a speciality of a double-shafted pug mill, fitted with expression rollers, to produce this result.

Cutting Table.—A most convenient hand power cutting table is one which travels longitudinally as well as laterally—known as the "Simplex" cutting table. The whole operation is performed by one attendant with one handle. A few power cutting tables are in use, some automatic and some not; but it is evident that, to supersede a hand table that requires but one attendant, the coming cutter must be automatic. The "Raymond" and the American Clayworking Machinery Co.'s automatic cutters have a most harmonious arrangement of all parts, and make a perfectly straight cut.

Driers.—The old fashioned system of open-air drying is, or ought to be, a thing of the past. Nowadays drying floors and tunnel dryers are recognised necessities. Tunnel dryers are of recent introduction into this country, but already some are giving good results, though their increased cost of construction may be against their general adoption for some time. The requisites in a drier are:—Non-liability to damage the green bricks, perfect regulation of the heat and air circulation, economy in construction and working; and the method which best achieves these results can only be obtained by varied experiment and careful observation.

Kilns.—The modern continuous kiln is fast superseding older types; it is being rapidly perfected, and the day is not far distant when it will be used for burning all kinds of material. A continuous kiln, to give the best results, must always be built to suit the material it is intended to burn, and the nature of the material must always be taken into consideration in designing the kiln.

Dry Press Bricks.—Up to the present time little has been done in this country in the making of dry press bricks, though in other countries, particularly in the United States, the best quality of facing bricks is made by this system. Where it has been tried in Britain it has not been altogether successful, but this result is due to a want of knowledge of the material best suited to this method, and ignorance of the machinery best fitted for it. Briefly stated, the method is as follows:—The clay is first thoroughly dried, preferably by being left for some time under a shed with a hot floor. It is then thoroughly ground in perforated mills, and being next elevated to the top of the building, it is there sifted, the finer particles of clay being delivered by rhones down through a hopper to the press, while the coarser material is returned to the mill. The fine clay is next delivered through a charger into moulds, where by plungers with increasing degrees of force it is formed into completed bricks. It is to be noted that different qualities of clay require different degrees of pressure.

These bricks require more careful steaming and harder burning than the bricks made by the plastic method.

Semi-Plastic System.—This system is generally applied where the material is of a shaley nature. The material is ground as already described in the dry press system, and is led from the rhones into a double-shafted mixing mill, where it is stirred up and mixed with a small quantity of water. From the mixing mill the clay is delivered into the pug mill, and from there it is pressed into moulds in a circular revolving table, or in a cylinder, according to the class of machine. From the moulds the bricks are then delivered automatically to the press, where under considerable pressure they are finished and taken direct to the kiln. This method of brick-making is best suited for treating the refuse heaps of coal and iron-stone mines, where these are used for making bricks.

Mr. J. A. Longden, Mr. A. Gilmour, Mr. A. Weatherilt, and Mr. H. B. Nash took part in the Discussion.

A vote of thanks was accorded to the author.

"THE BUFFELSDOORN AND ADJACENT DISTRICTS OF THE NORTHERN KLERKSDORP GOLD-FIELDS, TRANSVAAL."

Paper by William Smith.

Abstract.

I.—Geology.

Although much has been learned and recorded by competent geologists and mining engineers of the general formation of the Klerksdorp district, still there is much to be done before the all important point, the exact position of the Main Reef payable beds, is located along the lines of the formation. There can be little doubt that these beds will be traced from Randfontein to Klerksdorp.

The generally recognised succession of beds as known on the Rand and neighbouring districts can be more or less distinctly recognised and traced over the Klerksdorp district, with this difference, that the country generally is more disturbed and broken up by the presence of intrusive igneous rocks, and considerable areas are covered by the overflows from dykes and other centres of eruption. The disturbances caused and the extensive areas covered by the igneous action has rendered progress in prospecting very limited, and in most cases it has been attended with uncertainty and much expense. Boring on a large scale and to great depths is now well understood and carried out on the Rand, and it only requires that a systematic plan of prospecting by bore-holes be employed to settle the question of the position of the payable reefs. The fact that large areas are covered with sheets of ancient lava need not deter one from piercing them with the drill, as in all probability they will be found of a reasonable thickness, especially near the edges of the overflow, and merely a cover to the older gold-bearing formations.

The succession of strata from below upwards is as follows:—(1) Granites; (2) Schists; (3) Old and New Quartzites, Sandstones and Shales with Gold-bearing Conglomerates; (4) the Black Reef, lying unconformable to the above named; (5) Dolomites; and (6) the Magaliesberg and Gatsrand Sandstones and Quartzites.

Granite is found in large bosses appearing to the north and west of Buffelsdoorn; and resting on these bosses are the shales, sandstones, and quartzites of the Rand formation; and towards the east, the overlying Black Reef and Dolomitic Limestone, with a large area of igneous rock underlying and forming the footwall of the Black Reef. Igneous rock also occurs in large masses to the west of the Palmietfontein farm, and to the north on Cyferfontein farm. From the Doornfontein farm, about ten miles north of Buffelsdoorn, a rock similar to the Hospital Hill shales (which are generally taken as the index to the Main Reef series) can be traced in a north-easterly direction for several miles, and this would indicate that the Main Reef should be found on a more or less parallel line at about one mile to the south-east or on the Witrandjesfontein, Tweelingsfontein, and Rooikop farms.

The general dip of the formation is from 30 to 45 degrees south-eastward, and the strike trends from north-east to south-west. The igneous rock is chiefly amygdaloidal diabase, with other basic rocks. Coal is found in small basins overlying the dolomite; and one of these areas, situated near Koekemoer station, has been opened out and worked by the Buffelsdoorn Estate and Gold-mining Company (Limited). Large deposits of good coal are found south of Klerksdorp and the Vaal river in the Orange River Colony, and the coal is supplied to the Klerksdorp gold-mines at a reasonable price.

II.—The Buffelsdoorn Estate and Gold-mining Company (Limited).

This mine, one of the best equipped mines of the district, began in a small way, with but trifling development and a 10 stamps battery, and to-day has 200,000 tons of ore-reserves, and 100,000 tons of 4.97 dwts. gold-slimes conserved in dams. The mining and other rights are situated on the Buffelsdoorn (660), Request (137), Rietfontein (632), Eliazar (617), Rietkuil (337), Palmietfontein (697), and Stilfontein (381) farms.

The mine-workings comprise one main inclined shaft, 1,245 feet deep, the No. 1 west inclined shaft, 524 feet deep, and the No. 2 west inclined shaft, 539 feet deep. These shafts are connected by six levels; the seventh level is connected with No. 1 shaft, and is being driven westward to No. 2 shaft; and the eighth and ninth levels are being driven westward from the main inclined shaft towards No. 1 shaft.

The surface equipment consists of:—(1) The battery-plant, (2) the cyanide-plant, (3) the electric-plant, (4) the pumping-plant, and (5) the air-compressing plant. The battery-plant consists of 170 stamps of the ordinary gravitation heavy type pattern. Details of the plant are given in the paper.

The average working costs per ton of stone milled are as follows:—Mining, 10s. 9.94d.; redemption of capital, 4s.; transport, 4.54d.;

prospecting, 0.84d.; milling, 3s. 5.42d.; cyanide treatment, 2s. 2.57d.; native labour supply, 3.59d.; and the total cost of 21s. 2.90d. would be reduced about 10 per cent. if waste-rock, broken and thrown out in the sorting process, was taken into account.

The writer apologises for the brevity of the paper, which was written on the veldt, but hopes, at some future date, when he has left his regiment and returned to civil life, to write an extended paper.

A vote of thanks was accorded to the author.

"THE CULM-MEASURE TYPES OF GREAT BRITAIN."

Discussion on Paper by W. A. E. USSHER.

This paper was read at a previous meeting of the Institution of Mining Engineers (see Transactions, 1900, Vol. XX., p. 360).

Mr. Ussher referred to and quoted from a paper entitled "Notes on Certain Granitoid Fragments from the Culm Conglomerates" by Mr. A. R. Hunt.

Mr. James M'Murtrie took part in the Discussion.

The meeting was then adjourned.

WEDNESDAY, 4th SEPTEMBER, 1901.

Mr. JAMES S. DIXON in the Chair.

"THE PRODUCTION OF COPPER AND ITS SOURCES OF SUPPLY."

Discussion on Paper by M. EISSLER.

This paper was read at a previous meeting of the Institution of Mining Engineers (see Transactions, 1901, Vol. XXI., p. 315).

Mr. A. H. Bromly continued the Discussion.

"THE IMPERFECT PULVERISATION OF ROCKS BY MEANS OF STAMPING, AND SUGGESTIONS FOR ITS IMPROVEMENT."

Paper by E. D. CHESTER.

Abstract.

THIS paper explains the cause of the imperfect crushing by stamps as at present operated, owing to the restriction set up through using a fine screen, and trying to reduce the material at one operation, and suggests crushing in series and classifying. A trial run on hard Perthshire conglomerate in a stamp mill running at 94 drops per minute, with 1200 lb. stamps and 7½ inches drop, by first crushing through a screen 100 holes to the square inch, proved that 86.3 per cent. would pass through a 900 screen at the rate of 9.29 tons per stamp per 24 hours. The coarse sands not passing the 900 screen were recrushed in a battery of 1200 lb. stamps, dropping 4 inches, drops per minute, 144, resulting in 2.6 tons per stamp. The two above results give an average of 6.277 tons per stamp. Another quantity of rock was then crushed in accordance with the present practice, and only 4.64 tons were crushed, showing an increased output of 35.1 per cent. in favour of the 6.277 tons in series crushing, and with at least 25 per cent. less slimes.

The paper further points out that in dry crushing with rolls, as soon as the material enters the point of contact and becomes crushed it sets up a pack in a similar manner to what is done in the stamping operation. This pack lifts the roll, and consequently prevents fine crushing, as it allows particles of rock to pass through; and if a separation were made, it could be crushed in one operation to the required size. This is, of course, the reason why finishing rolls have to be adopted in many instances.

In dry crushing it is essential, as soon as the rock enters the rolls and becomes crushed, that it should be spread out so that the rolls can come into contact with the whole of the material, and still further reduce it. This result has been secured to a great extent by the Wegerif Roll (British patent, January 11th, 1900, No. 662), in which the rolls are so mounted, the one partially above the other, that their axes cross each other, or lie in parallel horizontal planes, but in different vertical planes, so that the planes of rotation of the rolls are oblique to each other, and consequently the particles passing between the grinding faces of the rolls are subjected to a tearing, disruptive, or spreading action (in addition to ordinary simple crushing or grinding), whereby the grinding action is rendered more efficient. This obliquity of the roll-axes involves a concave hyperboloidal configuration of the grinding or crushing faces of the rolls, in order that a continuous line of contact or bite may be obtained. As, however, the direction in which the material enters between the rolls more or less approaches the horizontal, but should be wholly in a downwardly inclined direction, it is essential, in order to secure an even distribution of the material along the line of bite, that this line of contact should itself be as nearly horizontal as possible, so that the material fed into the rolls will not gravitate towards one end of the line of bite. Were the rolls made in the form of a complete hyperboloid, either one or both of their axes would necessarily be placed out of the horizontal, and the efficiency of the rolls would in any case be seriously impaired.

One of the above-described machines, in a trial run, gave the following results: it used 14 indicated horse power, crushed at the rate of 150 tons in 24 hours, and reduced the material to such a size as would be suitable for catching the coarse gold and easy cyaniding. A sample of the resulting product was shown.

The Chairman, Mr. J. Stirling, Mr. J. A. Longden, and Mr. D. A. Louis took part in the Discussion, and the author replied.

A vote of thanks was accorded to the author.

"MINING AND TREATMENT OF COPPER ORE AT THE WALLAROO AND MOONTA MINES, SOUTH AUSTRALIA."

Paper by H. LIPSON HANCOCK.

Abstract.

INTRODUCTION.—The Wallaroo and Moonta Copper Mines are situated at the northern end of Yorkes Peninsula, about 6 and 11 miles respectively from Port Wallaroo, where the smelting operations are conducted by the same proprietary. The mines have been in operation for about forty years, and take in the chief cupriferous resources of the district. At the Wallaroo mines there are several ore-producing lodes, some of which are nearly parallel. The general strike of the main ore body is about North 75 degrees West. At the Moonta mines there are five ore-producing lodes, bearing on an average North 30 degrees East. The total value of the ore produced in connection with these mines has amounted to over £10,000,000. The quantity of veinstuff raised annually approximates 200,000 tons, giving about 37,000 tons of dressed ore yielding annually 4800 tons of the celebrated Wallaroo copper. The hands employed at the mines number about 2000. The main ore-raising operations are at depths varying from 1000 to 2000 feet, the deepest being about 2500 feet. The ore as raised consists chiefly of sulphides of copper, intimately associated with a matrix very similar to the surrounding rock formation. The bulk of this material needs comprehensive treatment to afford satisfactory results, the copper contents varying between 2 and 4 per cent. At the Moonta mines the country rock is felsite-porphyry—a plutonic igneous rock—intensely hard, with a specific gravity of about 2.67. At the Wallaroo mines the rock is chiefly a metamorphic mica schist of possibly Cambrian age, and though not so hard as that at Moonta, is tougher, containing considerable quantities of hornblendic material; specific gravity about 2.95. The weight and flaky nature of the waste causes greater difficulties in concentration. The Moonta mines ore is considerably richer than the Wallaroo, but the amount of waste in proportion to the ore much greater. The lodes are on the underlay; those at Moonta dip from 50 to 70 degrees. The underlay and intensely hard nature of the rock making crosscutting expensive, the shafts are sunk for the most part with the lode. Wheeled skips are utilised

instead of cages for raising the ore to the surface; many of these have a capacity of 45 cubic feet, holding about 28 or 30 cwt. of vein stuff. Passes, shoots, and bins are used extensively for speedy transport, and to facilitate expeditious hauling, which at the main shafts is at the rate of from 30 to 35 skips per hour. At Wallaroo mines overhead stoping is found effective. Ordinary stulls were formerly used where side pressure was not heavy. Where this pressure occurred it became necessary to timber with legs and caps. Where the ore body is sufficiently wide, the roof of the drives is supported on timber-work pillars, filled with mullock, on either side of the level. At Moonta both the overhead and underhand systems of stoping are followed. Whenever sides have been sufficiently rigid to be self-supporting, the underhand method has been preferred. The stulls have been of the simplest kind, namely, main timbers set in "hitches," with suitable "headings."

GRADING PLANT.—The landing brace at the shaft is of sufficient height to admit of sizing by gravity. The ore is dumped on to iron screens, which separate the various sizes of rocks; these are discharged into bins, and thence into railway trucks below. Crude material passing through $\frac{5}{8}$-inch holes is kept separate, and treated on a specially designed jig. Vein stuff passing through holes $\frac{7}{8}$ inch and $1\frac{1}{4}$ inch in diameter is treated separately on another specially adapted jig. Material rougher than $1\frac{1}{4}$ inch passes at the end of the sizing trommel into a bin, and is dealt with on the picking belt.

REDUCTION PLANT.—Rougher material and all crude vein stuff when poor, are fed into powerful breakers, which rapidly reduce it to a gauge of about $2\frac{1}{2}$ inches. It is then elevated, after passing through a revolving trommel to remove smaller sizes, to be discharged on a travelling belt. The trommel lets through such sizes as can be cheaply dressed by the various mechanical concentrators. Boys pick out the different classes of ore from the travelling belt. The solid ore is sent in the rough or crushed state to the smelters. Copper ores associated with special minerals are dealt with separately. But by far the greater portion of the material which comes on to the picking belt is low class vein stuff. This is conveyed in tipping trucks to large hoppers at the various concentrating plants; it is then passed, after the addition of water, between large crushing rolls of the Cornish type, and the reduced pulp is received by a revolving trommel which removes the coarser stuff, the remainder going to the jig for concentration.

HANCOCK JIG.—This machine was invented by the late general manager, Mr. H. R. Hancock, some years ago, to treat the immense quantities of low grade copper at these mines, where it has been most extensively used ever since; and it may be safely said that the life of this property has been prolonged considerably by the adoption of this invention in connection with the operations. The jigs have been adopted with great success by several of the Broken Hill silver mines in New South Wales, and also by mines in other parts of the Australasian Commonwealth. During the time the invention has been in use at these mines, about 4,000,000 tons of material have been passed through the various machines in operation. The capacity of the jig is great. One machine treats 150 tons of pulverised material in 24 hours, the cost of treatment being therefore low. Shafts, smalls and toppings jigs (also the invention of Mr. H. R. Hancock) are found exceedingly serviceable for various classes of material at these mines.

SLIME DRESSING MACHINERY.—From 12 to 15 per cent. is reduced to a fine state in crushing, and carried past the main jigs to settling pits. There are three classes of slime dressing machinery in this department, viz.—Round tables, belt and table vanners, and inclined soft treatment tables governed by self-acting gear.

LEACHING TAILINGS.—The coarser tailings from the dressing appliances are placed in suitable positions, where after adequate exposure to wind and weather, the sulphides corrode and by degrees become decomposed. These heaps vary in height, but generally range from 30 to 40 feet, and represent a total area of over 20 acres. The tops of the heaps are laid out in terraces. By a system of sousing, resting, and draining, a liquid is obtained from the base of the heap containing from 120 to 250 grains of copper to the gallon. The process of leaching has been carried on for some little time, but a plant is now nearing completion that will treat the large heaps, aggregating over 1,000,000 tons, in a very much more comprehensive manner from a large central station.

A vote of thanks was accorded to the author.

"A NEW DIAGRAM OF THE WORK OF MINE VENTILATION."

Paper by H. W. G. HALBAUM.

Abstract.

WHEN a gas expands in accordance with Boyle's law, the theoretic diagram of work is a rectangular hyperbola. When a gas flows through a given passage, an equally convenient diagram is supplied by an ordinary parabola. The particular case here considered is that of a given fan's capacity to ventilate mines of different resistances.

Let the tangential speed of the given fan be u, and let the total pressure thereby actually developed be H. Then, for the same fan,

$$\frac{u^2}{H} = \text{Constant} = \text{say, G.}$$

Therefore, the tangential speeds are ordinates, and the total pressures abscissae, to all points on the parabolic curve whose parameter is G. Since G is an inverse measure of the fan's ability to transform kinetic into potential pressure, G may be called the coefficient of transformation.

Owing to fluid friction within the fan, and escape of energy in the final velocity of the air, a portion of the total pressure is lost in performing useless work. Let this loss of pressure be l when the volume of the ventilating current is V. Then, for the same fan,

$$\frac{V^2}{l} = \text{Constant} = \text{say, M.}$$

Thus the volumes of air are ordinates, and the losses of pressure abscissae, to all points on the parabolic curve whose parameter is M. Since M measures the ability of the fan to pass volume against its own resistances, M may be called the parameter of the fan. In this parabola the product of ordinate and abscissa measures the aerodynamic power lost in useless work.

The balance of the total pressure is $h = H - l$. This is the effective pressure ventilating the mine. Then, for any given mine,

$$\frac{V^2}{h} = \text{Constant} = \text{say, } m.$$

So that the volumes of air are ordinates, and the effective pressures abscissae, to all points on the parabolic curve whose parameter is m. Since m measures the mine's susceptibility to the ventilative influences exerted by the fan, m may be called the parameter of the

mine. In this parabola the product of ordinate and abscissa measures the useful work performed in the ventilation.

To find m for any mine, it is sufficient to accurately measure V and h. To find M for a given fan, it is necessary to apply the parabolic law which affirms that the parameter is equal to the quotient obtained when the product of the sum and difference of any two ordinates is divided by the difference of their abscissæ. The volumes passed by a given fan are, under all circumstances, ordinates to the same M curve, and these are directly measurable. The corresponding abscissæ, however, being the invisible losses of pressure, are not susceptible of direct measurement. But if two factive mines of different resistance be constructed, and if the fan be run at uniform speed on each mine in turn, the difference of the measurable effective pressures becomes equal to the difference of the invisible losses of pressure, and thus the difference of the abscissæ in the M-curve becomes mathematically measurable, and the value of M is then deduced from the parabolic law just quoted. Having found M, l may be deduced and added to h. The sum is H, and since V is known,the coefficient of transformation, or G, the parameter of the remaining curve, is finally ascertained.

The skeleton diagram for the given fan can now be constructed. It consists of the two parabolic curves whose respective parameters are G and M. These curves have a common origin, or vertex, and a common axis, which it is convenient to lay horizontally. From the common origin, a common scale of ordinates may be erected perpendicular to the common axis. The m-curve may be dispensed with as unnecessary, for its abscissa is equal to the difference of the abscissæ of the other curves, and the height of its ordinate is found on the M-curve. Moreover, to be of any appreciable use, it would need to be drawn for a great number of mines, which would confuse the diagram unnecessarily. In the construction of the diagram, again, it is convenient to take the tangential speeds in feet per second; pressures and losses of pressure in feet of air-column; and volumes of air in thousands of cubic feet per minute.

To estimate the work of the fan on any mine m at any speed u, proceed as follows:—From the height u on the scale of ordinates draw a line parallel to the common axis until it touches the G-curve. The length of this line = H. The ordinate to the M-curve erected at the distance H from the origin is the volume the fan would pass at the speed u if it acted in the open air. The volume obtainable at the same speed from the mine m is measured by that ordinate to the M-curve whose abscissa is l. And

$$l = \mathrm{H} \times \frac{m}{m + \mathrm{M}}$$

The effective pressure obtained under the same conditions is

$h = H - l$. And in the same case, the ratios of the useful, useless, and total aerodynamic powers are the areas of the rectangles hV, lV, and HV respectively. By multiplying each rectangle by the weight of 1000 cubic feet of air, the ratios are converted into actualities.

It has been proved by experiment that fans which are cased, fitted with evasée chimney, and regulated by sliding shutter, conform very closely to the law delineated in the parabolic diagram of work.

A vote of thanks was accorded to the author.

"COKE-MAKING AT THE OLIVER COKE WORKS."

Paper by F. C. Keighley.

Abstract.

Introduction.—The Oliver Coke Works are located at Oliver, just outside the borough of Uniontown, Fayette County, Pennsylvania, U.S.A. This location is in the very heart of the choicest portion of the Connellsville basin of coking coal.

Coke-Ovens.—The plants at this time consist of 708 beehive coke-ovens, 12 feet 3 inches in diameter by 8 feet in height, inside measurement, which are laid out, for convenience in charging, at two different points a few hundred feet apart, and known as Oliver No. 1 and No. 2. There are 328 ovens at No. 1 Oliver, and these are laid out as follows:—One row of bank-ovens and one set of block-ovens, the ovens facing three yards or loading wharves and two railroad sidings. There are 380 ovens at No. 2 Oliver, laid out in three parallel sets of block-ovens, the ovens being arranged to face six coke yards or loading wharves and four railroad sidings.

The Oliver coking plant was erected by Messrs. Oliver Brothers, of Pittsburg, Pennsylvania, a little over ten years ago; and, as they were very extensively engaged in the iron and steel industry at that time, the works were laid out specially for the manufacture of coke for blast-furnace purposes. The coal for the coke ovens is taken from large bins (holding from 400 to 600 tons of coal) located at the hoisting shafts, and carried to the ovens by a train of three 200 bushels capacity steel larries and a locomotive, at each location. All tracks, both on the coke-ovens for use of the larries and on the railroad sidings, are of the standard gauge of 4 feet 8½ inches.

The charges of coal are run into the ovens directly from the larries, and these charges run for regular work as follows:—Mondays and Tuesdays, 130 bushels of coal per oven; Wednesdays and Thursdays, 140 bushels of coal per oven; and Fridays and Saturdays, 175 bushels of coal per oven. In case of shortage of orders or car-supply, these charges are differently scaled.

The yield of coke per oven varies, of course, with the charge. The average drawing per oven for a period covering 16 months was 4,602 tons* of coke. The output of coke for the year ending December 31st, 1900, was 466,618 tons. The capacity of the

* Throughout this paper the short ton of 2000 pounds is used.

works, if run full time every day for a year, is 500,000 tons of coke. The coke-drawing is all done by hand, by means of scrapers and forks, and the coke is loaded at the ovens by the drawer into wheelbarrows, and wheeled directly into the railroad cars. The works are equipped with 400 25-tons capacity standard-gauge railroad coke-cars of the open-top drop-bottom type. The coal, of which this coke is made, is taken from the celebrated Connellsville seam of coking coal, and is used for coking purposes just as it comes from the miner's pick. No crushing, washing, screening, or slate-picking is done; in fact, the coal is so pure that nothing of this kind is necessary.

ANALYSIS OF COKE.

Moisture.	Volatile Matter.	Fixed Carbon.	Sulphur.	Phosphorus.	Ash.
0.30	0.645	89.405	0.678	0.013	9.229

ANALYSIS OF COAL.

Moisture.	Volatile Matter.	Fixed Carbon.	Sulphur.	Phosphorus.	Ash.
0.600	29.50	63.10	0.94	0.014	5.85

The yield of coke from coal is about 67 per cent. There is about 3 per cent. of "breeze" in addition to the above, which at present is treated as so much waste, and carted to the ash-dumps. In common with other manufacturers of Connellsville coke, no attempt is made to utilise the waste-gases and bye-products from the coke-ovens. The cost of coke-making under the present wage scale is about 6s. 3d. ($1.50) per ton. It is the intention to increase the number of coke-ovens to 1100, making it the largest coking plant in the world.

The Chairman took part in the Discussion, and the author replied by correspondence.

A vote of thanks was accorded to the author.

"MINERAL RESOURCES OF THE PROVINCE OF QUEBEC, CANADA."

Paper by J. OBALSKI.

Abstract.

THE province of Quebec covers an area of 347,000 square miles, being twice as large as the British Islands, and extends for about 1700 miles from east to west and 600 miles from north to south, with a population of less than 2,000,000. It is practically crossed from east to west by the water-courses formed by the St. Lawrence and Ottawa rivers, dividing the country into two well-defined districts, which are drained by numerous and important rivers. The tributaries are only navigable for small lengths of their courses, but they are of great use for the drifting down of timber and afford important waterfalls, which are beginning to be used for motive power.

The country north of the St. Lawrence and Ottawa rivers is formed of metamorphic and eruptive rocks, known under the general name of Laurentian. The southern shore comprises several series from the Cambrian to the Devonian, with a few eruptive mountains, forming a continuation of the Alleghany chain. The immediate valley of the St. Lawrence and Ottawa rivers is formed by Lower Silurian limestone and shales; while towards the south the older Cambrian and pre-Cambrian rocks have been brought to the surface by a great fault running north-eastward. Devonian rock appears only at the surface in Gaspesia, forming the eastern part of the province, and Anticosti island.

Only a relatively small part of that large territory has been prospected; but nevertheless, from the geological study which has been made, we know what kind of minerals may be expected, although new discoveries may happen.

In the Laurentian formation the following minerals occur: Phosphates of lime, mica (white and amber), plumbago, magnetite, titanic iron, felspar, etc.. In the other series, occupying the south, are found copper ores, magnetite, hæmatite, alluvial gold, asbestos, chromite, soapstone, etc.

In the central district there are important indications of combustible gas and oil, and in the extreme west oil has been found. On both shores of the St. Lawrence the rock is generally covered

by alluvial drifts. Peat, bog iron ore, clay, and marble are found in abundance; while, where the rock outcrops, there is a large supply of material which is used for building and ornamental purposes and for lime-making.

Amongst this great variety of minerals must be deplored the absence of coal, which has to be obtained from Nova Scotia and Pennsylvania; but in many mining districts wood, so plentiful in this province, is used as fuel, and several trials are being made just now for the preparation and industrial use of peat.

IRON.—Although the iron industry in this district is the oldest established in North America there are only two small furnaces using bog ore, and they produce the highest quality of charcoal pig iron, 6700 tons having been made last year. Several attempts were made 30 or 40 years ago to smelt the magnetic ore found in the vicinity of Ottawa, the magnetic sand of Moisic, and the titanic ore of St. Urbain, but without financial success. Several mines of magnetite and hæmatite are scattered through the province, but the most important are the magnetic sand-deposits of Moisic, St. John, and Natashquan, on the northern shore of the Gulf. It is estimated that many million tons of ore, containing 70 per cent. of iron, practically free from phosphorus or sulphur, could be obtained by a proper concentration getting rid of the titanium, which is found as titanic iron with the sand: several machines have been introduced for this purpose.

COPPER.—In the vicinity of Sherbrooke large bodies of copper ore, yielding an average of 4 per cent. of copper, 35 per cent. of sulphur, and a little silver, are regularly worked with an average output of 30,000 to 40,000 tons a year. Part is used on the spot for the manufacture of sulphuric acid, the remainder and the burnt ore being shipped to the United States. Several other deposits, some of them of high-grade ores, were extensively worked about 25 years ago, and abandoned later for several reasons, but they may be again reopened.

GOLD.—In the Beauce district alluvial gold has been worked in an intermittent manner; the total production has been estimated at £400,000 (2,000,000 dollars). Actually these alluvials are only worked on a small scale.

ASBESTOS.—The asbestos industry is one of the most important having produced last year £150,000 (750,000 dollars) of raw material. The mines of asbestos are located in a serpentine belt, which is extensively worked at Thetford, Black Lake, and Danville. Asbestos is shipped to the United States and Europe.

CHROMITE.—Chromite is found near Black Lake. The ore is variable in quality, but contains less than 50 per cent. of sesquioxide of chromium; it is concentrated to reach that grade. About

2500 tons are obtained yearly, and sent mostly to the United States.

MICA.—In the Ottawa county amber mica is found and worked at many places, the value at the mines of the output being about £30,000 (150,000 dollars) a year. It is shipped uncut, on account of the high duty on cut mica, to the United States, where it is used in the manufacture of electric machinery. White mica also exists in several places, but it is not at present worked.

Among the minerals of minor importance is the apatite of the Ottawa region, where it is very abundant and was worked with success, at one time producing an average of 25,000 tons a year; but since the discovery of phosphate of lime in Florida and South Carolina the mines have become unprofitable.

A deposit of galena is being worked at Lake Temiscaming, and some other deposits of more or less importance are known but are not at present being developed.

In the eastern townships there is an antimony mine, not now worked, and also numerous deposits of soapstone.

In the Laurentian formation graphite, mostly in a disseminated form, has been worked, with but little success; a few concentrating mills have been erected, and some mineral is also shipped in the crude form to the United States.

Felspar is abundant, but finds a limited market. Sulphate of baryta is worked to a small extent. Molybdenite is found in a few places, but it is not developed. In Magdalen islands manganese has been discovered.

Some borings have been made for gas in the Trenton formation, showing good indications. In Gaspé prospecting for oil has been carried on for several years, and many wells have been bored to a great depth. Oil of a first-class quality has been found, but so far not yet in commercial quantity.

Granite, marble, and limestone of a good quality are found in all the formations of the province and used for the local building industry. Lime and bricks are manufactured at numerous places. Large areas of peat are found in many districts, but are not yet used. Ochre of good quality is manufactured near Three Rivers, and many other deposits are known.

The mines on all the lands not sold previously to 1880 still belong to the Government, which disposes of them by sales or leases at reasonable prices.

The total value of the crude products at the mines represents about £500,000 (2,500,000 dollars) yearly, 5500 men being employed in this industry. Transport in the open districts is easy. Wood fuel is abundant, and Nova Scotian coal is worth 16s. 8d. (4 dollars) a ton. Labour is cheaper than usual in America, 4s. (1 dollar) being the average wage of unskilled men. Water power has not been much used so far for mining purposes, but it may be used with proper transmission of power.

In conclusion, although the province of Quebec is not of the first rank as a mining country, the few industries so far developed are generally prosperous, and afford good returns upon the invested capital.

A vote of thanks was accorded to the author.

"THE THEORY OF THE EQUIVALENT ORIFICE, TREATED GRAPHICALLY."

Discussion on Paper by H. W. G. HALBAUM.

This paper was read at a previous meeting of the Institution of Mining Engineers (see Transactions, 1900, Vol. XX., p. 404).

Mr. J. T. Beard and Mr. G. Hanarte contributed in writing to the Discussion, and the author replied.

"GOLD DREDGING."

Discussion on Paper by W. DENHAM VERSCHOYLE.

This paper was read at a previous meeting of the Institution of Mining Engineers (see Transactions, 1901, Vol. XXI., p. 372).

The author replied to the Discussion in writing.

"GOLD-MINING IN THE ROSSLAND DISTRICT, BRITISH COLUMBIA."

Discussion on Paper by J. J. SANDEMAN.

This paper was read at a previous meeting of the Institution of Mining Engineers (see Transactions, 1900, Vol. XX., p. 401).

Mr. John Kirsopp, jun., contributed to the Discussion in writing.

"THE CONNECTION OF UNDERGROUND AND SURFACE SURVEYS."

Paper by Professor G. R. Thompson.

Abstract.

In the early history of coal mining in any district little difficulty is experienced in the survey of the workings which, by inclines or shallow shafts, open to the surface at many points. As the deeper coal is worked the royalties become larger, and more accurate underground surveys are required. These also must be accurately connected with the surface survey. In metalliferous mines the value of a small strip is often very great, and corresponding accuracy is required in connection with the surface. The mining engineer or surveyor will, in general practice, be required to make such connections with greater or less precision according to circumstances, and the paper examines the degree of accuracy attainable by the various methods in use.

The principal methods adopted for getting a common meridian to the two surveys are:—

1. The Magnetic Needle Method.—Using an ordinary 6-inch dial, the bearing of a line can be read to about five minutes of its true reading; hence in the underground and surface observations we might expect an error of 8 minutes or so, or a lateral deviation of 1 foot in every 480 feet traversed from the connecting point. Such a result would suffice for small surveys, where the proportional accuracy required was not great. If the underground and surface surveys have each been conducted with greater accuracy than this, and a more accurate connection by the needle is desired, this may be done—(1) by taking one direct and several indirect bearings of surface and underground lines by the combined use of theodolite and dial; (2) by using a needle with vernier attached, or the tubular modification with micrometer eye-piece, a reading of the needle's position to 3 min., 2 min., or even 1 min., being attainable. The limitations to the magnetic needle method are that the needle is subject to—(*a*) a yearly change, which must be known for the year and the place, and allowance made when connections are made at different dates as in extensions; (*b*) a daily change, which varies with the place and season from 1 to 8 minutes or so. The curve of daily change must be known, and a correction applied for difference of time between surface and underground observations, or the observations must be made near 8 p.m., when the

change is very slow, and the daily mean is recorded. (*c*) magnetic storms, during which readings should not be taken. Taking the above precautions, readings accurate to 1 min. could be obtained, but (*d*) local attraction, due to magnetic rock, may give a much greater error than this, and until such is proved to be absent, the method cannot be trusted.

2. TRANSIT THEODOLITE AND TRANSIT INSTRUMENT METHOD.—This method makes use of one shaft only. Let us suppose the length of the connecting line is 6 feet, and we wish to know its direction to one minute, we have to fix the direction of this line by fixing its two ends, and this must be done with such accuracy that the combined error will not displace the line more than one minute. Now in a 6-foot line a lateral error of 0.02 inch at one end will displace it by one minute, so that each point must be fixed to about 0.014 inch, and we must use a telescope of such power that each point can be adjusted to within this distance from the true direction of the line of collimation. If the shaft be 1000 feet deep, the telescope must allow this to be done at 1000 feet. The unaided eye can resolve two lines when the space between them subtends an angle of 1 minute, or slightly less, and can see them distinctly when they subtend a like angle. It can adjust two lines to superposition to about $\frac{1}{3}$ minute; consequently, to adjust the wire to within .014 inch in one observation we require a telescope magnifying 90 diameters. An error of 1 minute in the adjustment of the transit axis to the horizontal would displace the underground line $3\frac{1}{2}$ inches in a shaft 1000 feet deep, but its effect on the direction would be negligible unless the underground line were taken off at a very high angle. Vibration in all forms must be avoided in such a case as this, seeing that the angle of adjustment is about 0.2 seconds.

Should a connection of equal accuracy be required through a shaft 100 feet deep, the magnifying power of the telescope need only be 9 diameters—such a telescope as is possessed by an ordinary 5-inch theodolite.

3. TWO PLUMB LINES SUSPENDED DOWN ONE SHAFT.—To test how accurately a line could be transferred from the surface to the underground survey by means of plumb lines, the writer took two tempered steel wires, 0.02 inches diameter, and suspended them in a rectangular shaft 660 feet deep, giving a 5-foot base line. The wires were run over pulleys with V grooves in the rims, and bearings carefully turned for true running, and shoulders on axles to prevent side play. From each line in turn weights of 6, 13, and 19 lbs. respectively were suspended, and the wires allowed to vibrate with weights immersed in a pail of water, the position of rest being determined from the average of the greatest

and least readings during each swing as observed, through telescopes, on two scales placed behind the wire at right angles to each other, one telescope being on a theodolite roughly centred in line with the two wires, and used for extending the line underground. The three plummets were used to detect and determine any steady deflecting forces (such as air currents, spray from dropping water, etc.). Though the experiments were regarded as preliminary, and too few observations were taken to eliminate the effect of irregular impulses, yet the results from the three sets of experiments on each wire showed the connection to be accurate to 2 minutes of arc.

4. Plumb Lines down two Distant Shafts.—From Method 3 it is easily seen that, if two shafts are available, and a direct sight can be had between, this method can become very accurate; and if a direct sight cannot be got, the accuracy of the connection depends on the accuracy of the survey between the two plumb lines alone. In this case the line of survey should be as nearly as possible in the direction of the connecting line, and the distance between the two shafts should be considerable. The probable error of determining the traverse angles consists of three parts:— (1) Reading the angle, (2) bisecting the signal, (3) centreing the instrument at the station. In a 5-inch theodolite the first may be about 20 seconds, the second about 2 to 3 seconds, while the third depends on the length of sight available, and the care in centreing. The probable error in position of the last point of a traverse of twelve lines is discussed in the paper and illustrated by a figure; by traversing back and completing the polygon, the actual accumulated error can be determined, and this distributed over the polygon reduces the probable error, which in any case is only the same as would come in the underground survey itself. When the underground survey is circuitous and the shafts comparatively near, the lateral error in the traverse may become so great that the method fails for accurate connection.

5. Survey down Inclines.—As in 4, the error made in carrying an angle forward by traverse applies, but the error of sighting increases proportionately to the secant of the angle of inclination, as also the error due to centreing; and the probable error of each angle increases to such an extent that with high inclinations accuracy of direction cannot be maintained through many lines. Points, however, fixed by surveys down two distant inclines, may be treated in the same way as plumbed points in 4.

A vote of thanks was accorded to the author.

"A NEW CIVIL AND MINING ENGINEERS' TRANSIT THEODOLITE, FOR CONNECTING UNDERGROUND WORKINGS TO THE SURFACE, *VICE VERSA*, AND FOR GENERAL SURVEYING."

Paper by H. D. HOSKOLD.

Abstract.

THE writer devoted much attention to the improvement of surveying instruments prior to 1863, but the "Miners' Transit Theodolite" then introduced, and which he had in use prior to that date, although efficient for most surveying purposes, did not meet all the conditions proposed. Between that date and 1870 he conceived the idea that a portable transit theodolite might be constructed, with a hollow or perforated vertical axis, rendering it efficient for the object of sighting down a perpendicular shaft through the centre of the instrument, with a view to connecting underground and surface surveys with facility and great precision, the instrument also being adapted for general surveying.

The contrary case of producing a surface line through a perpendicular pit and in the same direction below ground often occurs where shafts are sunk to produce railway or sewer tunnels in a given direction, and for these operations a proper instrument is absolutely necessary.

An instrument was designed before 1870, but it was not until after 1893 that a design was placed in the hands of Messrs. John Davis & Son, Derby, who have constructed an instrument. It supplies admirably a deficiency long felt in surveying, because it is a perfect substitute for the portable astronomical transit instrument which was formerly employed exclusively for the object of connecting underground and surface surveys by the late Mr. Beanlands, Mr. Richardson (Severn Tunnel), and Mr. E. H. Liveing.

The great objection to the use of transit theodolites with long and powerful telescopes is the great height of the standards or Y's supporting the telescope, rendering such instruments top heavy, clumsy, and easily affected by vibration; but in sighting down the deepest shafts considerable power of telescope is needed in order to bisect two illuminated marks placed at the bottom of the shaft.

The telescope of this instrument is made much longer than is usual in order to supply the power needed. At the same time, the standards or Y's are made shorter than is usual, rendering the

instrument more compact and not easily affected by vibration; in fact, the half of the telescope is longer than the height of the Y's or standards, so that apparently the telescope would not transite. This difficulty is avoided by constructing the telescope tube in one piece, and causing it to slide in a sleeve or long socket forming part of the horizontal axis. This movement is brought into action by turning the head of a large milled screw attached to a pinion and rack formed in the sleeve, so that the object glass can be made to point perpendicularly and right through the vertical axis down a shaft, and it can also be arranged so that a sight in the vertical or zenith may easily be taken through a long and powerful diagonal eye-piece.

An exchangeable micrometer eye-piece, measuring angles to one second of arc, is fitted to the instrument, and is admirably adapted to find distances by the sub-tense mode without direct measurement with a chain. The instrument has also two spirit levels to its upper part—*i.e.*, one is attached to the vernier arms of the vertical circle, and the other, a very long and sensitive one, is attached to the opposite side of the telescope.

In addition, therefore, to the instrument being a transit theodolite, the spirit level renders it equal to the finest spirit level for levelling operations. It is supplied with a lantern and axis level, and also a long trough magnetic compass, with short and long diagonal eye-pieces. It is made in composite aluminium metal, and is comparatively light.

To connect an underground survey with the surface, the traversing stand of the new transit theodolite is fixed upon a platform over the centre line of a down cast shaft, and by moving the instrument laterally by hand, and a fine adjusting screw, the telescope is brought into the same vertical plane as two illuminated marks or electric lamps placed in the bottom of a shaft, and in line with the heading leading from it. When the illuminated objects appear in the field of the telescope, the slow motion screw of the traversing stand is moved, causing the vertical spider line in the telescope to bisect the illuminated objects. The telescope is then raised to the horizontal, and the underground line set out upon the surface, and in the same direction.

Mr. G. D. Ridley, Mr. J. A. Longden, Mr. James Stirling, Mr. T. Lindsay Galloway, Professor Henry Louis, Mr. J. Barton, Mr. C. C. Leach, and the Chairman took part in the Discussion. Mr. G. R. Thompson contributed in writing.

The author replied to the Discussion in writing.

A vote of thanks was accorded to the author.

"ALTERNATING CURRENTS, AND THEIR POSSIBLE APPLICATION TO MINING OPERATIONS."

PART II.

"THE PRACTICAL APPLICATION OF ALTERNATING CURRENTS TO MINING OPERATIONS."

Paper by SYDNEY F. WALKER.

Abstract.

IN the first part of this paper the writer dealt with the principles of alternating currents of electricity, and explained in what way they differed from continuous currents. In the present paper he proposes to show how alternating currents may be used in mining work, and the advantages of their use.

The advantages and the method of application may be divided into two sections, viz.:—

1. The distribution of energy over a large area.
2. The use of alternating current apparatus underground.

The tendency at the present time is, for economical reasons, to produce power at a convenient centre, and distribute it over the area to be served. Power, like so many other things, can be produced more economically in large quantities. At the present time, where a number of collieries are owned by one company, with perhaps an ironworks dependent upon the collieries for its supply of coal and coke, it is usual to have a battery of steam boilers at each colliery, sometimes more than one at each colliery, and often at different parts of the ironworks. The boilers are worked at pressures varying from 30 lbs. per square inch to 80 lbs., with, in a few cases, 100 lbs. and 150 lbs. Higher pressures than these cannot in many cases be used, because it is not practicable to use compound engines, and because there is so much condensation of steam during the time the engines are standing, and this condensation increases with the pressure. If the whole of the power can be generated at one centre for the whole of the works interested, pressures of 150 lbs. to 250 lbs. per square inch can be economically used, by means of triple and quadruple expansion engines, and considerable economies in coal consumption realised. It will be remembered that, in raising steam, it is the operation of converting the water at 212 deg. F. to steam at the same temperature that consumes the major portion of the heat, while the higher the pressure to which the steam is raised, the more work a given quantity will do. But when all the power is generated at one centre, the question of distribution comes in. In many cases the collieries lie at great distances apart, an outside distance of 20 miles not being excessive. If the power is to be distributed by electric currents, it is absolutely necessary to use high pressures on the transmission lines, while it is equally necessary to be able to use low pressures, 100 volts to 500 volts, in the lamps and motors. If 1,000 horse power has to be transmitted 20 miles, it will be practically impossible to lay down enough copper to transmit it at 100 volts; the pressure would be all lost; and it may be taken that economy in transmission varies approximately as the square of the pressure employed. At 1,000 volts the economy is 100 times that at 100 volts, and at 10,000 volts it is 10,000 times that at 100 volts, and this applies to losses in transmission, and to the size of the cables. In America they are using pressures up to 60,000 volts, and there can hardly be any doubt that for such distributions as sketched above, pressures of 10,000 volts and upwards will have to be used. Now, for pressures above 2,000 volts, it has not been possible, so far, to construct machines generating continuous currents that will work satisfactorily. The insulation problems involved in a revolving apparatus with high pressures have been so far insuperable. With alternating currents, on the other hand, no such trouble exists. The stationary or static transformer—consisting of a magnified induction coil, a mass of laminated iron plates, with two coils of copper wire embedded in them, or coiled round them, allows of all sorts of transformations, up and down, from low to high pressures, and *vice versa*, without any trouble. Hence alternating currents can be generated at any convenient pressure, transformed up to the pressure required for the line transmission, and transformed down again to any required pressure, at the points of consumption; and in addition, alternating currents may be transformed into continuous currents, where it is more convenient to use these. The advantages of using alternating-current apparatus for machine driving in mines are, the complete absence of a revolving commutator, with the attendant breakage of circuit and sparking in the electric motor, and the lower pressure employed in the revolving portion of the apparatus. The induction motor, the apparatus that would be most suitable for use in collieries, is actually a transformer in itself, in that it receives currents at any pressure in its stationary coils, where insulation can be accomplished with comparative ease, and transforms them into low pressure currents in the armature, or revolving portion of the apparatus, at the same time producing motion of revolution, only low pressure currents appearing in the revolving portion. The revolving portion of the apparatus also presents no breaks in its coils, except in case of accident, and there is no break of any kind in the circuit of which the revolving portion is a part, except for the purpose of securing a large starting torque, while this, again, is not absolutely necessary where the machine can be started off the load, and switched on to it afterwards. These advantages are very considerable for underground work.

Mr. J. L. Walters and Mr. G. A. Mitchell took part in the Discussion, and the author replied.

A vote of thanks was accorded to the author.

On the motion of Mr. G. A. Mitchell, seconded by Mr. J. T. Forgie, a vote of thanks was accorded to the Chairman, Mr. James S. Dixon, and he replied briefly.

On the motion of Mr. J. C. Cadman, seconded by Mr. W. N. Atkinson, a vote of thanks was accorded to the University Court.

The proceedings then terminated, and the business of the Section was brought to a close.

SUMMARY OF PROCEEDINGS

OF

Section VII.—Municipal.*

TUESDAY, 3rd SEPTEMBER, 1901.

Mr. E. GEORGE MAWBEY, Chairman, in the Chair.

THE CHAIRMAN'S ADDRESS.

By E. GEORGE MAWBEY.

Abstract.

IN opening the meetings of the Section the Chairman gave a brief address, in the course of which he said that, as representatives of the branch of engineering practice which is, perhaps, more closely identified than any other with the health of the people of the United Kingdom and the Colonies, it was fitting that municipal engineers should take a duly prominent part in the International Engineering Congress at what was possibly the greatest exhibition ever held away from London in the British Isles. It would have been difficult, if not impossible, to have selected a more suitable site for a great exhibition—and particularly for a congress of civil and sanitary engineers—than the city of Glasgow; which is the commercial capital of Scotland, the Manchester or Liverpool of the North, a seat of profound learning, and a veritable hive of industry. Indeed, comprehensive as the scope and character of the exhibition was, he considered it doubtful whether it could convey more vividly and strikingly an adequate idea of the indomitable energy, pluck, skill, and enterprise of the British race than was conveyed by the great manufacturing works of Glasgow itself, and the world-famed shipbuilding establishments and other gigantic centres of production on the Clyde. A mere enumeration of the vast and varied industries so successfully carried on in the city and

* The full Proceedings of Section VII. are published by The Incorporated Association of Municipal and County Engineers, 11 Victoria Street, Westminster, London, S.W., price 6s. 6d., post free.

its environs would occupy much more time than could be devoted to a brief address. He referred to one typical instance of the enterprise of the citizens of Glasgow, and took the opportunity to congratulate the civic fathers of the city, who had been the pioneers of British muncipial tramways, upon the inception and completion of one of the most important tramway undertakings in the United Kingdom. Even those who lived at a remote distance from the city of Glasgow had watched with the keenest interest the progress of the undertaking; and if their admiration had not been voluntary, it would have been compelled by the splendid way in which really phenomenal difficulties had been overcome as they had arisen. The principal characteristics of the scheme might be said to be that it was so thoroughly up-to-date in every particular; and it was evident that neither pains nor money had been spared to ensure complete success. The equipment of the Pinkston Power Station was especially interesting and instructive. The plant includes both British and American engines of the best types procurable in their respective countries; and an unique opportunity was here afforded of judging their relative merits when working under precisely identical conditions.

The speaker then briefly mentioned the papers which were to be read, and in conclusion remarked: "There is assembled here to-day a very large and representative body of engineers; and it will naturally be expected that from such a gathering much information will emanate as to research and experience, and that some new light at least will be thrown on the various problems of the day coming within the scope of our deliberations. I would therefore appeal to you to enter with earnestness into the discussions, and to let us have the advantage of your knowledge and experience; so that the public, as well as ourselves, may derive material and lasting benefit from the part we take in this great Congress."

"RESEARCHES INTO THE SYSTEM OF SEWAGE PURIFICATION AT HUDDERSFIELD BY BACTERIAL AND OTHER METHODS."

Paper by K. F. CAMPBELL.

Abstract.

THE sewage of Huddersfield contains a very large proportion of waste from the woollen trade and is therefore rendered very difficult of purification.

For a number of years the sewage was dealt with by special chemicals and subsequent filtration through very fine beds. This proved to be unsatisfactory and costly and was therefore abandoned.

Experiments were then conducted by the author on the three following methods of purification:—

1. Double contact of the raw sewage.
2. Chemical precipitation and double contact.
3. Open septic tank treatment and double contact.

For the first experiment two beds, one composed of very coarse clinker and the other of very fine, were constructed. The sewage was screened before being applied to the coarse bed by perforated sheet zinc, in order to remove the wool fibre. The beds were filled twice a day, and were allowed one complete day's rest per week.

The purification effected by the beds was good and constant, although not always sufficient.

A third contact was necessary when the sewage was concentrated.

One disadvantage of this system is that the sewage receives little or no mixing before being run into the bed, and also the rapid filling up of the coarse bed would alone cause the process to be condemned.

For the second experiment a small quantity of lime and copperas was used as a precipitant, the resultant effluent being further purified by contact beds. A number of beds have been constructed for the single contact of the tank effluent, in various ways, as regards material and size of material.

Those composed of clinker varying from ⅜-in. to 1 in.—a size

which is readily prepared—are found to be most suitable. A single contact of the tank effluent is not always adequate, a second contact being frequently required. This was given, and a satisfactory effluent continually produced on an experimental scale.

There is, however, a continual but slight decrease in the capacity of the beds, which will render necessary an occasional renewal of parts of the beds.

By allowing the sewage to slowly flow through an open tank a septic action was set up. This experiment was commenced in the autumn of 1900, but no permanent scum was formed until May, 1901.

The open septic tank has been treating sewage equal in volume to its own capacity per day.

The amount of sludge which accumulated at the foot was ·6 inch per week. The effluent from the septic tank, which is dark and contains a considerable quantity of black matter in suspension, is purified in two contact beds. The first is coarser than the second, and both are composed of destructor clinker. The effluent is frequently unsatisfactory, and the capacity of the coarse bed has considerably diminished during seven months' working.

It has been found that the matter which accumulates in the contact beds is only partly reducible, and as the suspended matter in the septic effluent is much greater than that present in the effluent from chemical precipitation, the beds will not need as much attention when an effluent from chemical treatment is being dealt with as with a septic effluent.

CONCLUSIONS.

1. That by no process can the formation of sludge be obviated.

2. When the crude sewage is treated in contact-beds, the rapid accumulation of matter in the beds renders the process impracticable.

3. That, by the use of a small quantity of lime and copperas, followed by contact-bed treatment, a satisfactory effluent can be produced.

4. That the contact-beds used for the purification of the effluent after chemical precipitation will not retain their capacity indefinitely, and that, in the course of a number of years, it will be reduced to such an extent as to render necessary the washing or riddling of the material.

5. That by the open septic process about 40 per cent. of the sludge is destroyed.

6. The septic effluent is not as amenable to subsequent contact-bed treatment as the effluent from chemical precipitation.

7. The capacity of the beds treating the septic effluent decreases

more rapidly than that of the beds treating the effluent after chemical precipitation, owing to the excessive amount of suspended matter in the septic effluent.

8. The septic effluent after double contact is frequently unsatisfactory.

The Discussion on this paper was taken with that on the paper by Lieut.-Col. Jones (see p. 258).

A vote of thanks was accorded to the author.

"SEWAGE TREATMENT."

Paper by Lieut.-Col. A. S. JONES, V.C.

Abstract.

TOWN and District Councils, in view of the great improvements of late years in arts and manufacture which have resulted from chemistry and electricity, expect similar advance in sewage treatment from applied science.

The paper touches upon "Chemical Precipitation," and the distinction between a popular interpretation of that term used in sewage treatment and its scientific limitation to the precipitate thrown down out of solution by a chemical re-agent added thereto; irrespective of matter, held in suspension while the sewage is in a state of agitation, to be deposited by its own gravity on the advent of quiescence.

Lord Bramwell's Royal Commission in 1884 crystallized the floating knowledge of experts on this distinction, and also on the necessity for adopting the separation system in sewage wherever possible.

But it led to a still more important advance of theory and practice by compelling the late Metropolitan Board of Works to take action as regards "a preliminary and temporary measure" by which "much of the existing evil" [of Metropolitan sewage discharge at Barking and Crossness] "will be abated."

Postponing the *permanent remedy* recommended by that Royal Commission, the Board directed their chemist, Mr. Dibdin, in consultation with Dr. Dupré, to experiment with samples of London sewage, with the following result—that after a while these two chemists laid down the principle of discarding chemicals and favouring bacterial action by extending the Bailey Denton "Intermittent Downward Filtration" until one acre of artificially prepared bed of coke was supposed capable of purifying one million gallons of sewage per diem.

Mr. Scott-Moncrieff and Mr. Cameron followed with rules for "Septic tanks," agreeing very closely with the practice of many old-fashioned cesspool builders; and Mr. Cameron laid great stress on the cover of such receptacles being rendered gas-tight, whereas the experiments lately conducted at Manchester, Leicester, Leeds, and Lawrence, Massachussetts, prove that open tanks are equally efficient, and, of course, such are much less costly to construct.

Among all the students of microbe action upon sewage, no one

has demonstrated that theory more completely than Scott-Moncrieff in his experiments at Ashtead and Caterham, which have been duplicated and confirmed on Filter No. 131 of the Massachussetts experimental station, as described at pages 452-3 of the Board's annual Report for 1899; but it can hardly be possible to erect such apparatus as his theory requires for a town's sewage, however useful from an educational point of view may be the results of such experiments.

While the long-promised report of Lord Iddesleigh's Royal Commission is daily expected, it may seem presumptuous for any-one to come forward with less authoritative statements about sewage treatment, and the writer offers, with great diffidence, some views formed on his 30-years' practical experience in dealing at one time with mixed manufacturing and domestic sewage, and latterly with an extremely strong and fresh residential sewage, and so strong that its chloride of sodium varies from 10 grains to 15 grains per gallon), from a population up to 30,000.

This leads him to insist on the importance of studying local conditions from the first inception of plans for sewage works, in each particular case, up to their completion, with the best available materials.

But when the best and most suitable works have been completed and paid for, the practice has often been for the sanitary authority to take little further interest in the matter, and to employ careless and incompetent workmen at inadequate wages to carry out the hourly varying duties, on efficient performance of which successful sewage disposal depends.

Mr. Cameron and several other engineers have devised automatic machinery for the more routine work of applying sewage to contact beds, but, in the opinion of the writer, anything of that kind will be found less profitable to authorities who adopt such appliances than to the inventors and manufacturers.

We have yet to learn the true average duration in satisfactory working of contact beds, under the most careful management and protection from insoluble matter but the recent experiments directed to that point are not encouraging, and if such beds have to be broken up and relaid every two or three years, the writer would suggest that the coke should be burnt as fuel after its life as a bacterial filter comes to an end.

With a well-arranged system of tramways it would be easy to keep one coke bed in use as a fuel store, and another in process of filling with fresh coke, while the rest of the series did duty as contact beds, and thus everything which bacterial life left behind would pass through the fire under steam boilers, for electric light and power, etc.

Passing from sewage *treatment under difficulties*, which necessitates great concentration of microbe energy on confined areas, the author proceeded to consider how the same energy has been used, and is still most extensively employed, by intermittent downward filtration, or broad irrigation, in sewage farming, and took as examples:—

1. Berlin, with some 20,000 acres under sewage, and convalescent homes flourishing in the midst of its well-irrigated land.

2. Paris, with a systematic distribution of its sewage to private cultivators over many square miles, in a suburban district.

3. Birmingham, Nottingham, Leicester, and other of our large cities and towns, where sewage farming has been carried on from day to day, with all that comes down an outfall sewer, for a long series of years.

In such cases there is always a complete natural protection from clogging, and some return in crops for labour in cultivation, while the freehold rises in intrinsic value as a Corporation asset for sewage or any other purpose—a factor often overlooked in comparative estimates of capital outlay on works without land.

Some account is then given of the camp farm at Aldershot, where the sewage of from 20,000 to 30,000 persons has been discharged for about 35 years, under good and bad management, in successive well-marked periods.

The paper insists upon good arrangements for dealing with sludge and screenings. Barging to sea, or pressing with lime into a portable cake of little or no manurial value, are sometimes resorted to for sludge, and a destructor fire is best for the screened rags and other debris, as used at Barking and Crossness; but both can be dug into the ground at once, or made into compost with farmyard manure, wherever land is available.

The reduction in quantity of sludge consequent on the use of septic tanks has been greatly exaggerated, and is outbalanced by increased difficulty of disposal introduced by its putrid smell, which is infinitely more disagreeable than that of the fresher sludge from ordinary settling tanks.

Reference is then made to the sewage disposal arrangements of Glasgow, which have received great attention from the city engineer and Corporation of Glasgow.

A Discussion on this and the previous paper, by Mr. Campbell, was held, and was taken part in by the following members:—Mr. Fowler, Mr. Midgley Taylor, Mr. A. J. Martin, Mr. J. Price, Mr. S. S. Platt, the Chairman, Mr. Thomas Stewart, Mr. J. Munce, Mr. Gilbert Thomson, Mr. A. J. Price, and Mr. Corbett. Col. Jones replied.

A vote of thanks was accorded to the author.

The meeting was then adjourned.

WEDNESDAY, 4th SEPTEMBER, 1901.

Mr. E. GEORGE MAWBEY, Chairman, in the Chair.

"THE BIRMINGHAM WATERWORKS."

Lecture by JAMES MANSERGH, President of the Congress.

THE city of Birmingham, with the district around it which the Corporation supplies with water, has an area of 130 square miles, and the present sources are six wells in the red sandstone and four or five comparatively small local streams. The present consumption of water at ordinary times is 18 or 19 million gallons a day; but during the last dry season there was a demand for 24 millions, which was met with difficulty. Thirty-five years ago, when the speaker was contractor's engineer on the railway which passes the district, he laid down on an inch plan the reservoirs in the Elan valley. In 1890 the Birmingham Corporation asked him to advise them on the matter, and the scheme was ready in time for the next session of Parliament and passed in 1892. The source of the supply was the River Elan, which is a tributary of the Wye. The distance from the lowest reservoir to the centre of the city was 80 miles, and between that reservoir and the service reservoir at Frankley was 74 miles, divided almost equally between cut-and-cover on the one hand and iron and steel pipes crossing valleys on the other. A map of England was shown, giving the relative positions of Birmingham, the watershed, and the aqueduct; also a plan of Manchester and the Thirlmere scheme, Liverpool and the Vyrnwy scheme, and the scheme suggested for London by Sir Alexander Binnie. Manchester had to carry its water 100 miles, Liverpool 66, Birmingham 74.

The district of Birmingham varies considerably in elevation. In the north-east corner it is 250 and in the south-west it rises to 800 above O.D. Fortunately the lord of the manor at Nantgwillt had for 20 years kept a record of the rainfall, which was most useful to the engineers. The mean rainfall was 68 inches, rising to 94 inches in years of heavy fall and falling to 44 inches in years of drought. The mean for three consecutive dry years was 55 inches. It is expected to obtain 72 million gallons a day, and, in addition, to supply 27 millions as compensation water.

When the speaker first delivered a lecture on this subject, at the Royal Institution some years ago, the question of stone dams was very much to the front—because the Bouzey dam, in France, had given way, doing an immense amount of damage—and he had therefore prepared a slide showing, for comparison, the section of that dam and of those he was building on the Elan. Slides followed showing how the flood water was dealt with during construction—a very serious business, as the quantity passing at the lowest dam was 700,000 cubic feet per minute; and then, starting at the beginning of the works, he explained how at the Caban dam they cleared the river bed of big boulders, built stanks enclosing the culvert sites, erected the culverts and diverted the water through them, and so obtained complete control of the floods. Slides were also shown of the old manor house of Nantgwillt and the house that Shelley once lived in; also of the church of Nantgwillt, which will be drowned under about 100 feet of water. A cross section of the cut-and-cover part of the aqueduct in course of construction was shown; also a slide of the Carmel bridge, eight or nine miles from the start. The cut-and-cover conduit and the tunnels provided for taking 72 million gallons a day; so that that work was done for all time. The constructions above ground were few, and those were built so as not to disfigure the country. Views of bridges were shown, including that crossing the Teme at Ludlow, 116-feet span, and a bridge crossing Deepwood Dingle, 80 or 90 feet high, built by Messrs. Morrison & Mason, of Glasgow. The Severn bridge was also shown. The pipes of this bridge were laid 40 feet above the level of the river and have to stand a pressure of 530 feet. There are five brick arches on one side and a steel arch of 150-feet span. The Worcester Canal had to be crossed with a bridge of 100-feet span, and the pipes were laid over as an arch. To get lateral strength three pipes were put in instead of two. The Frankley reservoir is semicircular in plan, as that provided the maximum of storage with a minimum of work. It is built with concrete asphalted, and the walls are blue brick faced.

Photographs of the filter works were also shown.

Eighty per cent. of the district could be supplied by gravitation, but the rest would require to be pumped.

All the work in the valley has been done without a contractor, being under Corporation administration; and after the lecturer obtained the committee's consent to this, he emphasised the necessity for providing houses for the workmen. Then he produced designs of the huts he proposed to erect. In the lodgers' huts the keeper and his wife have a good living-room, a couple of bedrooms, scullery, and all decent sanitary appliances, and the men have a large room in which there are eight single cubicles; so that each man is decently provided for. The result has been that a nucleus of good steady men, in whom reliance can be placed, is kept constantly on the job; and that is an enormous advantage for works of this type. For the married foremen and leading artisans of the better class there are huts of a different class, embracing altogether five types. The lecturer then described and illustrated the village, built to accommodate the men, which contains about 1200 people. There are schools, a recreation hall, baths and wash-houses, and complete water and sewage works; also a general hospital and one for infectious diseases; but this has been very seldom used, on account of the precautions taken to keep out small-pox and typhoid. There is what is called a doss-house, into which all men who come on tramp are put in quarantine for a week, under the observation of the doctor. They also have to take a hot bath and use a clean nightshirt; and their clothes are disinfected. They go to work; but they are not allowed to go to the village until they have passed out of quarantine. This has been found a useful plan in guarding against infectious disease. A picture of one of the wards in the general hospital was shown. A matron and a nurse are in charge, and one or two more come from Birmingham if necessary. There had not been anything serious—accidents, cases of pneumonia, and other minor cases. The bridge leading to the village is a suspension bridge over the River Elan; and here there is a gate-keeper, whose business it is to examine all carts taking provisions into the village, to make sure that no spirits or intoxicating liquors are introduced. There is also a village superintendent, whose business it is to generally supervise and to see that the regulations are carried out and all sanitary rules adhered to. The superintendent is also the bandmaster. The canteen-keeper has no interest in the sale of beer, and the Corporation has been able to make a substantial profit; the money being spent for the benefit of the men employed upon the works, on the schools, hall, recreation grounds, sports, entertainments, etc.

The Chairman, Mr. Harpur, and Mr. Weaver took part in the Discussion.

Mr. Mansergh replied, and a vote of thanks was accorded to him.

"DISPOSAL OF SEWAGE."

Paper by A. B. M'Donald.

Abstract.

The disposal of sewage is a question that does not admit of universal solution. The methods adapted for a rural community are as widely different from those applicable to a great industrial centre as they are from the sanitary arrangements of a residential establishment. The aim of the present contribution to the subject is intended to afford the members of the Congress such information regarding the Glasgow Main Drainage Scheme as may render their visit to the works of the Corporation more interesting than it might otherwise prove.

The Main Drainage Scheme was authorised by special statutes in 1891, 1896, 1898, and 1901. The included territory stretches along both sides of the River Clyde for a distance of about 15 miles, the superficial extent being 39 square miles.

The drainage area is divided into three sections, each separate from the others, with works for the disposal of the sewage. The first of these, authorised in 1891, and doubled in area during the last session of Parliament, is about 11 square miles in extent, one half being situated within the city and the remainder within the County of Lanark. The works for the disposal of this sewage are situated at Dalmarnock. The second section, authorised in 1896, includes the remainder of the municipal area on the north side of the river, the Burghs of Partick and Clydebank, with intervening parts of the Counties of Renfrew and Dumbarton, the whole extent being 14 square miles. The works for the disposal of this sewage are in process of construction on the river bank at Dalmuir, 7 miles seaward from Glasgow. The third section, authorised in 1898, comprises the whole of the city on the south bank of the river, along with the Burghs of Rutherglen, Pollokshaws, Kinning Park, and Govan, with various residential and rural districts situated in the Counties of Lanark and Renfrew. The extent—14 square miles—is likely to be increased by the inclusion of the Burghs of Paisley and Renfrew. The works for the disposal of this sewage are to be constructed on the river bank at Braehead, about 4 miles up stream from Dalmuir.

The three different sections were shown in distinctive colouring on the sketch map accompanying the paper.

The Dalmarnock works are constructed, and have been in successful operation since May, 1894.

The daily volume of dry-weather sewage is at present 16 million gallons.

The dry-weather sewage to be ultimately treated at Dalmuir is 49 million gallons, and at Braehead 45 million gallons.

For the collection and disposal of these 94 million gallons of sewage there will be constructed 30 miles of sewers, from 2 feet 6 inches in diameter to 10 feet, calculated to discharge, in addition to the sewage, an amount of rainfall equivalent to one-quarter of an inch per day or 189 million gallons of combined flow.

The leading features of the Northern Scheme are:—an outfall sewer to convey the drainage of the higher levels to Dalmuir; an intercepting sewer to collect the drainage of lower levels of the city; an intercepting sewer to collect the drainage of the lower levels of Partick; and a third intercepting sewer to convey to Dalmuir the drainage of the Burgh of Clydebank. The Glasgow and Partick intercepting sewers are pumped into the outfall sewer at Partick bridge, the lift being 35 feet. The Clydebank intercepting sewer is pumped at Dalmuir, the lift being 15 feet.

More than one-half of the Glasgow sewage is carried to Dalmuir without pumping. The whole combined sewage is delivered at Dalmuir above tidal level into the precipitation tanks.

Sewers on the south side of the river:—The pumping station at Pollokshields raises the low-level sewage 35 feet. There is another pump at Braehead, where the lift is 25 feet. The sewage of Paisley and Renfrew will require to be pumped at Braehead. The Braehead works, like those at Dalmuir, have the great advantage of river frontage.

The treatment adopted at Dalmarnock is chemical precipitation by means of under-surface continuous flow. The sewage is complex and most intractable, the suspended matters varying from 20 to 250 grains per gallon. The chemicals employed are hydrate of lime and sulphate of alumina.

The Sewage Committee intend to adopt at Dalmuir and Braehead the same method, except that sludge presses are to be dispensed with and the liquid sludge with greater economy carried out to sea.

The working result at Dalmarnock is that every trace of suspended matter is removed and 30 per cent. of purification attained, calculated on the basis of oxygen absorbed in four hours at 27 degrees Cent. The sewage at Dalmarnock is discharged into a tidal stream of vastly superior volume, exceeding by forty times the quantity of sewage. At Braehead and at Dalmuir 94 million gallons of sewage will come in contact with 3000 million gallons of tidal water.

The works at Dalmarnock, originally designed by the late Mr. G. V. Alsing, were at first arranged for intermittent precipitation in connection with coke filters. Recently it has been found desirable to extend and convert the Dalmarnock works. The precipitation tanks are now worked in continuous flow and filters abandoned, as the process has deteriorated the effluent instead of improving it.

The precipitation tanks at Dalmuir are to be worked on the under-surface continuous-flow system. They are more favourably situated than those at Dalmarnock. Each is about 750 feet in length, allowing opportunity for more complete precipitation than at Dalmarnock and effecting a saving in the reduced proportion of chemical agents.

Last year the author was instructed to report upon the extent to which bacterial methods might be adopted at Dalmiur, with a statement of the relative cost, and entered upon a joint investigation with the late Mr. W. Santo Crimp, M.Inst.C.E. The investigation showed that the capital expenditure alone at Dalmuir would be at least ten times greater than the outlay for ordinary precipitation works, without taking any account of the cost of renewing the filtering plant.

Careful observation has been made of the working of an experimental plant at Dalmarnock for bacterial treatment of sewage, the cost being £1000, exclusive of the original charge for the construction of the tanks.

The plant consists of one open septic tank and four first- and four second-contact beds.

One of the large precipitation tanks (superficial area 426.94 square yards, capacity 200,000 gallons) was utilised as a septic tank.

The result of the tests made in working this experimental plant exhibit the surface required for this method of sewage treatment; thus:—

	Acres per Million Gallons.
Test No. 1	5 acres for one filling.
Test No. 2	8.3 „ „
Test No. 3	9.4 „ „
Test No. 4	7.7 „ „
Test No. 5	8.1 „ „

The paper gives tables and figures relating to the working of the system in use and the experimental plant.

The Discussion on this paper was taken with that on Mr. Weaver's paper (see p. 265).

The author replied, and a vote of thanks was accorded to him.

"MUNICIPAL SANITATION."

Paper by WILLIAM WEAVER.

Abstract.

INTRODUCTORY remarks upon the general character of the paper. The author does not confine himself to specialities and details.

Sewerage and Drainage.—Advance in sewer systems during the past fifty years. Sewers, adequate size, good flow, non-nuisance outfall. Surface water. Ventilation. House drainage. Supervision bye-laws. Intercepting traps. Simplicity of construction. Costly details increase rent and the housing difficulty.

Water Supply.—Pure, free, and unstinted. Public and private ownership of supply. Proposed new (London) bye-laws.

Habitations and their Occupants.—Rules as to building construction; space; water supply; sanitation; increased cost of building; trade union limitation of output; migration from country; crowding into towns. Workers can help themselves to a large extent. Municipal efforts to retard national decadence. Crowding in relation to rent. Sanitary defects of dwellings can be dealt with. Sanitary shortcomings of occupier are not dealt with. Verminous Persons Act. Sanitary nuisance, whether man or matter, should be dealt with. Parks and open spaces. General power to acquire land should be vested in the Local Authority.

Highways.—Formation and laying-out generally. Impervious road pavements. Scavenging. Watering. Motor traction.

Refuse.—Street refuse. House and trade refuse. Destructors. Steam power.

General observations. Baths and wash-houses. Abattoirs. Disinfecting chambers. Infectious hospitals. Municipal lodging houses. Public libraries. Technical schools. Public conveniences. Health visitors.

The Discussions on this paper and on Mr. M'Donald's paper were combined, and were taken part in by Mr. Midgley Taylor and Mr. George Chatterton.

The authors replied, and a vote of thanks was accorded to them.

The meeting was then adjourned.

THURSDAY, 5th SEPTEMBER, 1901.

Mr. E. George Mawbey, Chairman, in the Chair.

"RECENT TRAMWAY PRACTICE."

Paper by James More, Jun.

Abstract.

In dealing with this subject, one has some difficulty in deciding what the term "recent" may mean. It may mean recent as compared with practice 20 years ago, which period covers many different systems of traction; or it may mean recent as compared with five years ago, which practically means electric traction, with a small amount of cable traction.

Electric traction in this country can hardly be considered of much practical value any longer back than five years, but it has greatly developed and matured in that time. The writer will, therefore, confine himself to a review of this method of traction, with a brief observation on the few cable lines in this country.

Regarding the permanent way, however, it is worth considering over a longer period, as it applies to all methods of traction in principle, only differing in degree as to stability under the different methods.

RAILS.

During the last twenty years there has been a considerable change in the section, chemical composition, and physical qualities of these. Until about 1885 there were many built-up systems used. Some of these were fairly successful with the light cars used for horse traction, but failed completely when steam locomotives were used. About 1880 light sections of girder rails were used to some extent, about 58lbs. to the yard.

GIRDER RAIL.

In 1883 the girder rail was generally adopted, to the exclusion of most others, and the weight was increased to from 80 to 100 lbs. per yard. The fish-plates, however, were as a rule much too light. The usual standard lengths of rails at that time were 24 ft. At the present time 45 ft. may be called the standard, although some have been rolled 60 ft. long. The sections have also much improved.

STEEL.

Ten years ago the common percentage of carbon was 0.35. At the present time the steel used for tramway rails contains from 0.55 to 0.65 per cent. of carbon.

FISH-PLATES.

There has been great improvement in fish-plates and in joints generally. There are also numerous different designs of sole-plates etc., all meant to minimise the pounding at the rail joint when the cars pass over.

POINTS AND CROSSINGS.

There has not been any important improvement in these excepting that at the present time the cast steel is somewhat harder by the addition of manganese. This was first adopted by Mr. R. A. Hadfield, M.Inst.C.E., of Sheffield.

Chilled iron points and crossings are becoming rarer every day for tramway purposes, but the writer thinks this is only due to the makers not making their patterns to suit the heavy electric cars.

ELECTRIC TRACTION.

As regards the electric traction of the present day, the writer thinks it is unnecessary to discuss any other than the overhead system, as this is the only system that has shown good financial results. The conduit system may become a financial success, but it is doubtful. The heavy initial cost is almost prohibitive, being more than that of the cable system.

At the present day we may take it that the 500 volts continuous current is the standard. Recently, however, there has been high potential alternating current tried on the Continent, with alternating motors on the cars. It cannot be said, however, that this has yet proved to be a success.

POWER HOUSE.

In the modern power house there are several kinds of different boilers adopted, some of the tubular marine type, and others of the water tube type, such as the Stirling and Babcock & Wilcox boilers.

These latter are specially useful where space is restricted, and where a lighting circuit is used in the same station as the traction circuit. There are, however, numerous engineers who will, if it is at all possible, adopt the old-fashioned Lancashire boiler with Galloway tubes. The writer is among that number.

Of course it is advisable in all installations to use an economiser, so as to raise the temperature of the feed water. These or exhaust steam heaters are generally adopted now, and effect a very substantial economy.

The type and speed of the engine vary to a great extent, but the practice is almost invariable to have direct-driven generators—that is, to have the generators fixed on the crank shaft of the engine.

Conveyors, stokers, piping, injectors, feed pumps, generators, etc., are discussed.

FEEDERS.

The feeder insulataion adopted is generally paper or bituminous insulation. Sometimes they are laid in ducts or conduits, and threaded after the conduits are completed. In other cases they are laid in iron troughs and run in with solid bitumen. Both methods have their advantages, which, however, are dependent on various circumstances.

TROLLEY WIRES.

The trolley wires are usually divided by section insulators into half-mile sections, any half-mile of which can therefore be cut out at the section boxes, which are placed in pillars on the footpath or underground pits.

WIRING.

Where the road is very wide there is no doubt the central pole with short arms is the correct thing. There are cases, however, where roads are too narrow for this, and too wide for the side pole system. In this case, sometimes there are span wires fixed by rosettes to buildings on each side of the street, and in other cases poles are put up with a span wire between. Again, there is the side trolley system, where, in no case, the trolley wire is over the centre of the track. This is advisable where it is practicable, as there is less danger of accident to the trolley pole.

POLES.

The poles are made of steel tubing, tapered in some cases, and in other cases made to three different diameters shrunk one on another. The latter are somewhat cheaper, but there is no doubt that the tapered pole has a better appearance.

CARS.

As to the cars, there is no doubt that the bogie car with the maximum traction truck is easier on itself and on the road, and more suitable for fast running. The four-wheeled car, however, is more generally used, as it has been found that the smaller cars with a fast service pay better than large cars with a slow service.

MOTORS.

It is usual only to have two motors either on a bogie or a four-wheeled car, but in many cases, where the district is hilly and the bogie type is adopted, it is advisable to have a motor on each axle —that is, four motors in all.

In the working of tramways, the modern, up-to-date manager fully realises that an essential factor to good financial results is to get the highest mileage per day out of his cars, of course with due time being allowed for dropping and picking up passengers. There are towns in this country where, in the writer's opinion, pick-up passengers are sacrificed for the sake of high mileage, and numerous accidents are caused which might be avoided. To facilitate this high mileage, it is becoming customary to fix stopping places at different parts of the route, and there is no doubt that this has tended towards the increasing of the mileage of the cars, but in the writer's opinion it is at the expense of the receipts in so far as pick-up passengers are concerned, especially where ½d. fares are charged for short distances.

The paper contains numerous specifications and particulars of materials and plant.

The following members took part in the Discussion:—Mr. Thomas Hewson, Mr. J. Price, Mr. A. H. Campbell, Mr. Fowler, Mr. Brodie, the Chairman, Mr. Harpur, Mr. J. Lobley, Mr. Kenway, and Mr. Broome.

The author replied, and a vote of thanks was accorded to him.

"THE PROBLEM OF THE HOUSING OF THE LABOURING CLASSES; WITH SPECIAL REFERENCE TO SUBURBAN DISTRICTS."

Paper by A. H. CAMPBELL.

Abstract.

The subject was dealt with under the following heads:—

1. THAT this is a pressing problem is evident from the great attention it is receiving at the hands of legislators, local authorities, and private companies.

2. That, by reason of the growth of population in urban areas, the clearance of insanitary areas, and the tendency to congregate, the problem will not disappear, but, like the poor, be ever present with us, and in an increasing measure.

3. That the problem deals not merely with the erection of houses, but is four-fold:—

(*a*) It is a social and economic problem.
(*b*) It is a transport problem.
(*c*) It is a structural problem.
(*d*) It is a financial and legislative problem.

4. To satisfy the four-fold demand set up by these four sets of circumstances, the following conditions are necessary:—

(*a*) The co-operation of private philanthropy and the municipal powers and authorities.

(*b*) Greatly increased facilities by road and rail for conveyance from the "heart" to the circumference of our great circles of population.

(*c*) Dwellings erected should be upon perfectly approved plans, so that each house or single tenement does not in itself become an overcrowded "unit."

Referring to this last condition the author makes the following statements and conclusions:—

(1) That the accommodation offered by each unit should be sufficient to house a family without being cribbed, cabined, and confined.

(2) That such accommodation can best be provided by the self-contained house or single tenement design (as shown in drawings accompanying the paper.

(3) That it is impossible, however, to erect a house on this plan to let at such a rent as the occupier can afford to pay, and as will repay all the outgoings and charges upon the property.

(4) These charges consisting *inter alia* of repayment of capital and interest thereon, local taxation, embracing sanitary, educational, police, and poor law, are exceedingly and unjustly heavy, and should be readjusted by fresh legislation.

(5) That such legislation should be upon broad and well-conceived lines, suited to the circumstances created by the attempt of local authorities to solve this problem.

(6) Any fresh legislation should provide—

(*a*) For extension of the periods of repayment and for reduced rate of interest on moneys borrowed for this purpose.

(*b*) Nationalisation of the following charges:—

(1) Poor law administration.

(2) Education.

(*c*) Enlarged powers for Local Authorities, entitling them, under proper safeguards, to purchase, hold, lay out, and develop land, so that the object aimed at may be more nearly realised.

7. To sum up, the great object is—

The provision of healthy homes for the labouring classes.

To let such homes at remunerative rents, that the low and uncertain wage-earner with a family can afford to pay.

The efforts of Local Authorities should be directed towards providing such dwellings at rents suited to the local conditions, but in every case this provision should be for the poorer class only, unable to afford the rent of the better or larger-sized dwelling provided by private enterprise.

To secure the foregoing, unity of action is needed by Local Authorities.

Statistics and drawings bearing upon the subject were submitted.

The Discussion was taken part in by the following members:—the Chairman, Mr. Lobley, Mr. Cooper, Mr. Munce, and Mr. Price.

The author replied, and a vote of thanks was accorded to him.

"COAL-MINING SUBSIDENCES IN RELATION TO SEWERAGE WORKS."

Paper by F. W. Mager.

Abstract.

THE object of this paper is to direct attention to the anomalous nature of the protection against subsidences, from mining operations, of sewerage works as compared with the protection afforded by the law to the highways which they underlie.

Alterations in gradients and cross-levels of highways are comparatively of minor importance, and in most cases when they occur they may be easily remedied; yet a subsidence of a highway constitutes technically a public nuisance. Against the person causing such subsidence an indictment will lie, and he makes good the subsidence at his own expense.

Alterations in the gradients of sewers virtually terminate the existence of the section affected, and give rise to actual nuisance, with serious results from a sanitary point of view. That being so, it would be imagined that a similar legal remedy would be provided; but no such remedy is open, and reconstruction must be done at the sole cost of the authority.

The Public Health (Support of Sewers) Act, 1883, might be thought from its title to have been framed for the purpose; but, in the first place, a district could not afford to put the Act into operation, and, if it could afford to do so, what might be left of the collieries would not be worth working.

The cost depends upon the amount of support necessary. In the author's district it would entail the purchase of seams known as the 'yard," the "seven-foot," the "shallow," and the "deep," having a combined thickness of 24 feet. Other coal seams and ironstone bands exist but are not worked.

The amount of lateral support required is not so readily arrived at. The angle of dip, direction of strike, the nature of the "bottom stone" and depth from the surface all affect the result; and unless a sufficient width be provided the sewer will be "pulled," that is, will subside from insufficient lateral support.

Where the other conditions are favourable, for a mine 300 yards deep a minimum width of 50 yards is requisite. Thus, for each yard run of sewer, minerals possessing a superficial area of 50 square yards and a thickness of 24 feet, equal to about 250 tons

weight, would be purchased. The value of the royalty, adding the usual allowance for interference and compulsory sale on a moderate valuation, would work out at £4 to £5 per yard run of sewer. Such a sum is evidently quite prohibitory.

Undue interference with a vital national industry would also be a fatal objection to the Act, if there was the least likelihood of any Council putting it into effect.

That being the case, the remedy for subsidence is clearly not purchase of support; but its more serious effects may be guarded against by designing sewerage schemes with regard to the levels which will obtain when subsidence has ultimately taken place, and in such a way that main points of outfall will not be affected.

This having been done, the cost of modifications of level of particular sections consequent upon subsidence posterior to the execution of the works should, by analogy with the law as to highway surfaces, be thrown upon the coal owners.

A reference to works recently designed by the author will illustrate this. A certain low-lying district which was being entirely undermined had to be sewered, but the sewer had to cross a fault and discharge to works constructed on land beneath the surface of which coal did not exist. The upper end of the system consequently subsided, while the lower end or outfall did not. On reaching the outfall the sewage had to be pumped four feet as the levels then stood, and the author determined to fix the site of the pump on the side of the fault not liable to subsidence and to put in the floor of sump at such a level that after every seam of mineral had been won and after the workings had settled down solid any point of the sewer would still be at a higher level than the inlet to the sump and thus an adequate fall be still obtained.

On the coal measures side of the fault the workings were in the hands of two separate owners and were broken up by two minor faults. Subsidences will, as a result, be irregular for some time, and the levels of individual sections of the sewer may have to be modified more than once. To avoid fracture of the pipes from movements of the ground they were shallow socketed and jointed in clay, and to keep them water-tight, should the joints become drawn, they were surrounded with puddle. This method will also allow the pipes to be readily taken up and relaid when modifications of the level become necessary. These modifications should evidently, and in spite of the law as it now stands, be carried out at the cost of the coal owner.

What is required is that the law should be so amended that after such works as the author has indicated have been carried out any subsequent modification of level, such as could not be avoided in the original construction of the sewerage system, should be done at the cost of the coal owner.

To call upon a coal owner to provide mineral support at his own cost, and thus maintain sewerage works at their original level, would be to force him to sacrifice valuable property, and to interfere with the working of his mine in such a way as would not be tolerated and has been shown to be unnecessary; but to call upon him to reconstruct public works laid down in public highways which have been damaged by him for his profit does not appear to the author to be unreasonable where such reconstruction may be done without excessive cost.

This argument holds good for damage to all public services beneath roads and streets, but obviously not for works constructed by agreement or under powers of a provisional order on private lands. The author suggests, in conclusion, that the subject of the foregoing notes is one deserving of more attention than it has hitherto received.

Details of the work alluded to were shown on drawings accompanying the paper. The special method of construction of the sump was necessary owing to the ground being of a most unstable nature. A driving chain, instead of belting, was adopted for power transmission to economise buildings. This has proved highly satisfactory.

On the motion of the Chairman a vote of thanks was accorded to the author.

The proceedings then terminated, and the business of the Section was brought to a close.

SUMMARY OF PROCEEDINGS

OF

Section VIII.—Gas.*

TUESDAY, 3rd SEPTEMBER, 1901.

Mr. GEORGE LIVESEY, Chairman, in the Chair.

CHAIRMAN'S ADDRESS

By GEORGE LIVESEY.

Abstract.

THE Chairman, in declaring the Section open, gave a short address, in the course of which he traced the progress of gas lighting from the days when, one hundred years ago, Murdoch introduced a system of gas lighting into the factory of Boulton & Watt, at Birmingham; and a few years later the first gas company was established to light London. From the early days of gas there has been, and still is, a general desire to reduce the price. At first in almost every place of importance rival gas companies competed with each other for custom during the first half of the century. Competition, however, killed itself. The last effort in that direction was the formation of the Great Central Gas Company to supply the city of London and the Surrey Consumers Company to supply South London; whereby the price of gas was temporarily reduced from 6s. to 4s. per 1000 cubic feet in 1850. The companies soon came to the conclusion that competition was suicidal, and allotted a separate district to each company—thus creating a monopoly of the supply of gas in London. The example of London was followed in other large towns. Hence so many "United Gas Companies." In 1860 Parliament sanctioned the districting in the whole of the Metropolis; and henceforth competition ceased. Then came a period of great prosperity. Gas had no competitor; for candles, and oil at from 5s. to 7s. per gallon, could not be so

* The full Proceedings of Section VIII. are published for the Committee of the Section by Walter King, 11 Bolt Court, Fleet Street, London, E.C., price 5s., post free.

regarded. Many companies' capitals increased; and, to protect the consumers, Parliament was led, in 1860, to introduce the system of testing the illuminating power and purity of the gas—legislation that has never done an atom of good, but an infinity of harm, to the public; and it has culminated in the elaborate and costly and worrying system in vogue in the Metropolis.

From the early days of gas lighting up to the end of the century the public, and gas makers also, have believed that gas of as high an illuminating power as possible was the desideratum. Instead of trying to develop the lighting power of the gas, the idea was to make it as rich as possible in hydrocarbons. Then, to prevent the inconvenience of dirt and smoky flames, burners were used that certainly accomplished that object; but they gave very little light. Burners of the regenerative class were all important steps in increasing the duty per cubic foot, until Welsbach's wonderful invention capped, and seems destined to supercede them all, by the introduction of an entirely novel and really scientific method of obtaining light from gas. The consumers now have it in their power to get out of 5 cubic feet of gas per hour anything from 5 to 150 candles from ordinary coal gas; whether it be nominally 10, 15, or 20 so-called candle power.

What a useless absurdity does this make of all the illuminating power tests! Photometers, that for forty years have given so much trouble, caused so much anxiety to, and wasted so much of the time of, gas managers, and have also caused so much loss to the consumer, are now proved to be, what they always have been, most useless instruments, and must sooner or later have their woodwork converted into firewood, and their metal consigned to the old-brass tub—to trouble gas managers no more.

Reverting to the historical summary, the period of fictitious prosperity, with nothing in the shape of competition, lasted about ten years (to the early seventies). Then appeared the first serious competitor, in the shape of cheap mineral oil; and a few years later the electric light entered the field. Gas had no longer a monopoly as a lighting agent. But Parliament, at the instigation of the Local Authorities, instead of relaxing the restrictions increased them. The old legislation, dating from 1847, governing the price of gas and the rate of dividend, was adapted to competing gas companies. When that competition ceased—which was the real protection of the public in the matter of price—the legislative enactments had no effect on the price; while they gave ample protection to the shareholders' dividends. In fact, it separated rather than drew together consumers and shareholders. This was remedied by the sliding scale, introduced in gas legislation in 1875—its sole merit being that it identifies the interests of consumers and shareholders, and, in effect, makes them partners. Whether or not it is the best means for accomplishing that object may be questioned. The sliding scale as embodied in gas legislation, supposing it to be the best known means of accomplishing the object in view, at present stops half way. There is another to be included in the partnership. The speaker tried to make a triple partnership—capitalist, employee, and customer; and the results of twelve years' working have greatly exceeded expectations. If, ten years ago, anyone had said that the employees in 1901 would have £140,000 invested in the stock of, or on deposit at interest with, the South Metropolitan Company, the author should have pitied his ignorance; for of such a result the author never dreamed. The result of about seven years' working in the Crystal Palace District Gas Company is equally satisfactory. In a sense better even than the money earned and saved by the men is the feeling of mutual confidence and goodwill that exists between all ranks in both companies. The workmen of another large company have, with practical unanimity, just accepted the system, as the men at Chester did a few months ago; and profit-sharing without shareholding was, about two years ago, adopted at the Corporation gas works at Stafford.

Since gas ceased to hold the monopoly of light, nearly thirty years ago, the advance and improvement in its manufacture, and its increased uses, have been greater than ever—more especially during the last decade. The South Metropolitan Company used 637,583 tons of coal in 1890, which increased 77 per cent. in ten years. Gas not only more than holds its own as an illuminant, but, since its monopoly as an artificial light ceased, it has come very largely into use for cooking, heating power, and manufacturing purposes. By means of the "slot" meter it has taken almost universal possession of workmen's dwellings, and by the Welsbach mantle it has distanced all competitors in the beauty and cheapness of its light. We hear of decaying industries; but with such vigorous growth, instead of decay there is abundant life, that gives promise of more uses and greater usefulness than ever. The future of the gas industry rests with engineers more than its past has done. The first and greatest need of the gas industry is that the supply of men should be maintained. Technical science will not save the national industry; but men who love work more than play, and who will put their heart and brain into their work, are the necessity of the age. Technical training is very good and necessary; but you must first "catch your hare," or rather, find your engineer, before you train him. And then take care that you do not convert him into a man of mere routine—a simple copyist. The making of plans and sections and the calculation of strains are not his highest work. It is not by the repetition of old designs and ideas that progress is made. We need engineers who will look ahead, anticipate as far as possible public requirements, and then bring all their skill to meet them.

The gas industry wants freedom to do its best for both the public and itself. Legislative restrictions should be removed, and the suppliers of gas left free to do their best to meet the needs of their customers. The great public need is cheap gas of good heating power. We are much behind places on the Continent in this important advance; and we shall do well to follow their example. With Welsbach mantles at 2½d. each—the price at which they are now being obtained from Germany—only heating gas will be required; for incandescent lighting must then become universal. Therefore, let the engineer "take time by the forelock," forecast the future, and devise a satisfactory method of producing the gas that the near future requires.

A last word, referring to the relations of the public authorities with gas companies. What other article of utility has come down from 10s. to 2s.—the same article, and not something different? The public does not know the extent and value of the service. The gas consumers in Glasgow are indebted to their gas engineer for a saving of £60,000 per annum. When such possibilities rest with the gas engineer, it is surely but necessary to mention the fact to ensure to the capable engineer the consideration and the treatment he deserves.

Dr. Leybold, on behalf of the German Association of Gas and Water Engineers, expressed thanks for the opportunity which had been extended to them of participating in the Congress.

"NOTES ON THE VARIOUS SYSTEMS OF GAS LIGHTING IN USE AT THE GLASGOW INTERNATIONAL EXHIBITION."

Paper by the COMMITTEE.

Abstract.

THERE were four systems of gas lighting in use:—

I. The Welsbach high-pressure incandescent system.
II. The Scott-Snell self-intensifying gas lamp.
III. Kitson's incandescent oil light.
IV. Acetylene gas.

THE WELSBACH HIGH-PRESSURE INCANDESCENT SYSTEM.—The installation of the Welsbach high-pressure incandescent system extended from the Bank Street entrance to the main entrance of the Exhibition buildings, and along the length of the main building as far west as the Art Galleries, the total area of the ground illuminated being about 20 acres.

There were about 140 cast-iron, ornamental columns, each surmounted by a single lantern of the Welsbach "shadowless" pattern, and containing a cluster of three burners, consuming 30 cubic feet per hour at a pressure of 8 inches; the illuminating power from the cluster being 1000 candles. There were also 12 columns, each carrying three lanterns, and 10 columns, each with five lanterns; each lantern being fitted with three burners in a cluster as above described. There were in all, therefore, 162 columns, carrying 226 lanterns and containing 678 burners, giving a total illuminating power of 237,000 candles. The gas consumed was about 10 cubic feet per hour for each burner; and, at the price of 2s. 6d. per 1000 cubic feet, the total cost for the gas consumed in the whole installation amounted to rather less than 17s. per hour.

The compressing plant consists of two sets of Keith's patent "Duplex" automatic gas-compressers. The motive power was water, drawn from the street mains; and the working was entirely automatic. Each set of compressors consisted of two pumping cylinders, with the motors fixed on the top, combined with a regulating arrangement for controlling the gas pressure and the speed of the motors and pumps. The quantity of water used is 0.86 gallon per 10 cubic feet of gas. At the price of 4d. per

1000 gallons, the cost of water for compressing 1000 cubic feet of gas therefore only works out to 0.34d. The special mains laid in the ground for the high-pressure gas were divided into two sections, with a bye-pass valve between them, so arranged that either set of compressers could be used to supply either section or all the burners.

It was estimated by the Welsbach Company, who supplied the lanterns and burners, and who maintained the latter, that the mantle renewals would not exceed 12 per burner per annum. Welsbach Kern high-pressure burners were used throughout the installation. These require no chimney. The lighting was very effective. In any part of the area lighted, small print could be read with ease.

The Scott-Snell Self-Intensifying Gas Lamp.—Between the Prince of Wales Bridge and the new Exhibition Bridge, on the north-west bank of the Kelvin, 32 lamps were erected by the Scott-Snell Self-Intensifying Gas-Lamp Company, Limited. Each lantern contained one burner. The pressure of the gas is raised in the lamp itself by the waste heat of the flame. The lanterns used were square, and were provided with a special governor immediately under the burner; and this maintained a constant pressure at the burner of 8 inches. The gas consumption of each burner was 10 cubic feet per hour, giving an illuminating power of about 330 candles.

The self-intensifying arrangement was placed in the top of the lantern, but cannot well be described without reference to drawings. In close proximity to this installation the company had a show-room, where diagrams and the working of the lamps were seen and explained.

Kitson's High-Power Incandescent Oil Lamps.—The Kitson Lighting and Heating Syndicate, Limited, erected in the eastern portion of the grounds, extending from the south-east bank of the Kelvin and including the area where the Japanese, Canadian, and Russian Sections were situated, about 100 columns, each carrying a single lantern with two burners in each. The light from each lantern was stated to be of 1000 candle power.

The system consists of the combination of an oil-burner and incandescent mantle. The oil (which is a specially prepared, highly refined, hydrocarbon oil, having a flash point of about 110 deg. F.) was stored in steel cylinders placed in the square base of the columns. The oil is first vaporised by the heat of the flame. It is then burned in incandescent burners with mantles. Air is pumped into the oil receiver until a pressure of about 50 lbs. per square inch is obtained. This forces the oil through small copper or bronze tubes to a vaporising tube, where it is vaporised by the heat from the mantles; the arrangement being such that only a minute quantity of oil is subjected to the heat at one time. From the end of the vaporising tube, the oil vapour passes into a mixing tube on the top of the reflector, where sufficient air is drawn in for supporting combustion. The mixture then travels down to the burners, where it is burned inside a mantle, as in incandescent gas lamps.

The consumption of oil was stated to be 0.1 gallon per hour for 1000 candles. With oil at 9½d. per gallon, and including renewals of mantles, etc., and time and attention to the lamps, the cost was stated to be less than a penny per 1000 candle hours.

ACETYLENE GAS.—*The Bon-Accord Acetylene Gas Lighting.*—The Bon-Accord Acetylene Gas Company, Limited, erected a plant for 220 lights of 25 candle power each; and the Press Pavilion, Band Stand, and Flint's Tea Rooms (all situated in the eastern portion of the grounds) were lighted by acetylene gas.

The carbide of calcium used was that manufactured at the Falls of Foyers, in Inverness-shire. The carbide containers are of cast iron, and are set in a rectangular tank, of wrought iron and steel, surrounded by circulating water, which insures the gas being given off at a comparatively low temperature. From these containers the gas passes to the holder, thence to the acid waster, and forward through the purifiers and regulator to the distributing mains.

The automatic generators only produce the gas according to the supply required.

The Home and Colonial Acetylene Gas Syndicate's Lighting.—The Agricultural Hall and Home Farm buildings were lighted by the Home and Colonial Acetylene Gas Syndicate, Limited. The plant selected for this section was M'Conechy's non-automatic or storage system. The gas was made during the day and held in storage until required. By this means the moisture is eliminated and burner troubles are unknown.

M'Conechy's patent generator is of the "drown" order. The water used to work off the carbide is contained within a jacket round the top of the generator, and its flow is controlled by a tap on the outside. The carbide chamber is sunk into a well of water, and is square in form. The carbide container is round, and perforated with holes. As the water slowly rises round the container, the gas evolved escapes through the holes and percolates through its own residual—namely, the thick lime water; and it is thereby thoroughly purified. The carbide container is placed in the centre of the square chamber. The removal of the residual is both cleanly and easily effected, as the square chamber has handles; and by lifting the manhole off, it is quickly cleared out.

The gas made by this system is said to be free from all trace of odour when burning. Several portable automatic lamps were shown.

The Manchester Acetylene Gas Company's Lighting.—Messrs. W. Moyes & Sons, of Glasgow, agents for the Manchester Acetylene Gas Company, Limited, had a 60-light machine at work, consisting of Kay's acetylene gas generators and Frank's purifier. The plant was very compact. Besides lighting their own showroom, the model cottages of Messrs. Lever Brothers, Limited, some distance away, were lighted from the same apparatus. Here also were shown a number of the "Phos" acetylene lamps and burners.

The Patent Paraffin Gas Lighting Company's Exhibit.—An oil-gas plant, capable of supplying 50 lights, was in operation, belonging to the Patent Paraffin Gas Lighting Company, Limited, of Glasgow. The gas is made from crude shale oil; and it is stated that from 12 gallons of oil 1000 cubic feet of 60 candle power gas can be obtained. It is used with Welsbach incandescent mantles, as well as with open-flame burners.

"GOBBE'S 'QUENCHING' PRODUCER."

Paper by FERNAND BRUYERE.

Abstract.

A GREAT saving can be effected in the manufacture of water gas, either carburetted or not, by modifying the usual method of quenching coke in the open air, and by adopting steam while the coke is at a red-white temperature; such as it is when drawn from the retorts or coke ovens. The commercial attainment of the reaction, $H_2O + C = H_2 + CO$, which invariably occurs whenever coke and water are brought into contact at a temperature of 600 degrees Cent. (1112 degrees Fah.) or more, is arrived at by the quenching producer designed by M. Emile Gobbe.

The quenching producer, briefly described, is in the form of a vertical chamber of a certain height, constructed so as to reduce to a minimum the loss of heat by radiation. The different openings required for working the apparatus are so arranged as to prevent any air getting in. The method of working is as follows. The coke, on being taken from the retorts or coke ovens, is received into tip-waggons, which are then emptied into the apparatus through the door provided in its upper part. A supply of water, in the form of steam or fine spray, is led into the bottom of the vessel. The size of the quenching-producer is calculated from the amount of coke to be extinguished and the time allowed, according to the exigencies of the make, so that the coke may reach the bottom of the producer quenched as desired.

It is in the upper part of the apparatus, where the temperature is sufficiently high, that the reaction takes place. In the lower part of the vessel the coke is at an insufficient temperature to cause the decomposition of the water; but, by its contact with the rising flow of steam, the coke becomes extinguished as it falls by imparting the heat it still has to the steam. The water, in becoming gradually heated to the required temperature to enter into the reaction, quenches the coke which reaches the lower part of the apparatus extinguished; where it is picked, sorted, and afterwards lifted either by forks or by mechanical elevators.

The gases formed, consisting chiefly of hydrogen and carbon monoxide, differ considerably from water gas made by other processes, and are particularly suitable for use for motive power; for lighting (either directly or after carburetting); or, better still, for heating the retorts in gas works.

The paper contains calculations relating to the yield per 70 kilos. of coke—the residual of carbonising 100 kilos. of coal—fed into the producer. The results show that 12.06 kilos. of steam are required to quench the 70 kilos. of coke and 8.04 kilos. of coke take part in the reaction with the steam. The density of the gases produced will be .67 kilo. per cubic metre, and the volume 30 cubic metres for 70 kilos. quenched.

The yield, therefore, will be 3.73 metres per kilo. of coke consumed in the producer.

It may be claimed that the gases made by the quenching producer are purer than those obtained in the manufacture of water gas. They have also a higher calorific power, and are therefore more suitable for various uses. The combustion of the 30 cubic metres of gas made by the coke (70 kilos.) left from the carbonisation of 100 kilos. of coal is capable of giving a larger number of calories than that developed from coke used in the Siemens producer. The distillation of the fresh charge of coal to be carbonised can be effected by the gas made from the residual in the quenching producer. In the Siemens producers the coke used is 14.80 kilos. per 100 kilos. of coal carbonised. In the quenching producer it will be 8.04 kilos., which is an economy of more than 45½ per cent. The gas made by the quenching producer will not cost half the price of water gas. The make of serviceable gas per kilogramme of coke is double; which is obvious, seeing that there is no coke consumed in order to feed the incandescent mass, as in the ordinary way of manufacturing water gas. The quenching producer will do away with the troublesome fumes arising from extinction in the open air and will prevent the loss of carbon caused by ordinary extinguishing. The apparatus costs little to erect. It is simple to manage, and does not need any reversing of sensitive and dangerous currents. In short, the adoption of this invention in gas works will, in the author's opinion, be most advantageous; because water gas made in the most economical way possible has the further merit of being purer and of greater calorific power.

In the absence of the author the paper was taken as read.

A vote of thanks was accorded to the author.

"THE UTILISATION OF WATER GAS IN THE DESTRUCTIVE DISTILLATION OF COAL."

Paper by Professor VIVIAN B. LEWES.

Abstract.

WITH the permission of Mr. George Livesey, and the co-operation of Mr. Sydney Y. Shoubridge, a long series of experiments were carried out during the summer months of 1900 and 1901 at the Crystal Palace District Gas Works upon the lines indicated by the author in a paper upon "Water Gas and its Recent Continental Developments," communicated to the Incorporated Institution of Gas Engineers in May, 1900.

The author pointed out that the formation of tar during the destructive distillation of coal was partly due to the distillation from the coal of hydrocarbon vapours, which afterwards condensed as liquids in the tar, and partly to decompositions and interactions taking place in the upper part of the retort among the hydrocarbons which were there subjected to contact with the heated crown of the retort and to the action of radiant heat, with the result that many compounds which would have been of value as illuminants in the gas became broken down into methane, hydrogen, and carbon, together with naphthalene and other hydrocarbons which went into the tar. He suggested, therefore, that a considerable economy in the manufacture of illuminating gas might be effected by passing a stream of plain water gas through the retort during the process of carbonisation, owing to the fact that the flowing water gas would carry the rich hydrocarbons out of the retort before the detrimental secondary reactions could take place. To test the accuracy of this theory a series of experiments were commenced at the Crystal Palace District Gas Works in July, 1900, with the horizontal retorts used for carbonisation in the ordinary manner. At first six beds, having seven retorts each, were employed; but subsequently the experiments were conducted with twelve beds, containing seven retorts each. The retorts were 20 feet in length and 22 × 16 inches in cross section, and were heated by regenerative furnaces, and charged by power stoking machinery. The water gas was made in an "Economical" water gas plant, and was conveyed from the holder to the retort house by a pipe specially provided. This pipe was continued over the retort bench just above the bridge pipes along one side, and a connection was made from it to the top of each ascension pipe on the same side of the bench. The dip pipes on this side were blocked, and the hydraulic valves closed. The

water gas descended the ascension pipes on this side, passed through the retorts, and up the ascension pipes on the other side along with the coal gas.

The gas was tested in a standard London Argand burner with a $6 \times 1\frac{7}{8}$ inch chimney, but it was found that when consumed at a rate of 5 cubic feet per hour an excessive proportion of air was drawn into the flame, and its illuminating efficiency was reduced, while the best results were always obtained both with plain coal gas and with mixtures of water gas with coal gas when the rate of flow was adjusted until a 3-inch flame in the chimney was obtained. Mr. Shoubridge properly objected that when the gas was sent out into the district the gas manager would not test the gas under this favourable condition, but would use the Referees' Table Photometer, and adjust the rate of flow to give a 16-candle flame, and therefore that this latter method of testing should be adopted in these experiments. All the results quoted in the present paper were therefore obtained by adjusting the rate of flow to give a 16-candle flame and then calculating the results to a 5 cubic feet rate.

When using the water gas it was soon found that the addition of small proportions resulted in but little gain, but that, as the proportion of water gas was increased, the gain in candle-feet per ton (volume of gas per ton × illuminating power ÷ 5) became more and more marked.

The conclusion deduced from the experiments with horizontal retorts was that an addition of about 40 per cent. of water gas during the first three hours of carbonisation of each charge is the most suitable proportion of water gas to employ, and this was confirmed in the following year by experiments conducted under more satisfactory conditions with inclined retorts.

Mr. Shoubridge having completed the erection of a new bench of 70 inclined retorts in the early part of the year 1901, the upper mouthpieces of these were provided with pipes for the introduction of water gas, and a long series of experiments were then carried out with extremely satisfactory results. Although little or no change was detected in the composition of the tar, a notable enrichment of the water gas was effected, and the results make it perfectly clear that a gas manager who has been supplying a 16-candle gas can, by simply putting in a blue water gas plant and utilising 40 per cent. of this gas in the retorting, turn out between 14,000 and 15,000 cubic feet of 14.5 candle gas per ton, without any alteration in his heats or general procedure. Even with coke at a high price, the cost of water gas made by the Dellwik process should not exceed 3d. or $3\frac{1}{2}$d. per thousand cubic feet, and with water gas at the higher figure an economy of 25d. per ton of coal carbonised can be effected.

Inclined Retorts, 1901.

	Coal alone. Average Seven Days' Trial.	Water Gas added ½ hour after Charge & continued for 3½ Hours.	Water Gas added 1 hour after Charge & continued for 3 Hours.	Water Gas added immediately after Charge and continued for 4 Hours.	Water Gas added immediately after Charge and continued for 2½ Hours.	Water Gas added immediately after Charge and continued for 3 Hours.	Water Gas added ½ hour after Charge & continued for 3 Hours.	Water Gas added immediately after Charge and continued for 2 Hours.
Water gas added per cent., ...	...	21·9	25·5	27·8	37·6	40·1	42·0	45·6
Average illuminating power (table), candles, ...	16·55	14·83	14·68	14·74	15·27	14·85	14·40	13·74
Candle-feet per ton, ...	32,792	37,582	38,235	41,343	40,936	43,703	42,984	40,467
Increase in candle-feet per ton per cent., ...	...	14·6	16·6	26·0	24·8	33·2	31·0	23·4
Total make per ton, cubic feet, ..	9,907	12,671	13,023	14,024	13,404	14,715	14,925	14,726
Tar, per ton in hydraulic main, gallons, ...	8·3	7·7	7·6	7·4	7·3	7·4	8·07	8·1
Gross Heating power, calories per cubic foot	152·6	133·9	128·8	122·5	126·7	125·8	127·2	126·0
Net heating power, calories per cubic foot, ...	138·8	122·7	118·2	112·7	117·6	118·7	116·8	117·1
Carbon monoxide per cent., ...	7·19	10·0	...	12·0	13·2	...	14·0	17·0
Water gas added per ton of coal carbonised, cubic feet	...	2,276	2,654	3,057	3,667	4,215	4,415	4,615

The principal results obtained are shown in the following table, but the author is of opinion that by introducing hot instead of cold water gas, and by a more careful proportioning of the rate of flow of water gas to the rate of evolution of gas from the coal in the retort, results yet more favourable can be obtained.

The Discussion was taken part in by the following members:—Mr. G. R. Love, Mr. E. H. Millard, the Chairman, Mr. W. Grafton, Mr. T. Glover, Mr. W. R. Herring, Mr. Charles Hunt, Mr. S. Y. Shoubridge, and Mr. J. W. Helps.

The author replied, and a vote of thanks was accorded to him.

Communications from Mr. Thomas Holgate and Mr. D. H. Helps have appeared in the technical press since the Congress, and are incorporated in the proceedings.

"THE AUTOMATIC LIGHTING AND EXTINGUISHING OF STREET LANTERNS."

Paper by A. ROTHENBACH, Jun.

Abstract.

FOR many years past, attempts have been made in the direction of lighting and extinguishing street lamps by some automatic or mechanical means, which would be more reliable and less expensive than the present system.

With the introduction of the Welsbach burners for the public lamps, arose the desire to light them in a way similar to that usual with electric, incandescent, and arc lights; and from that time date most of the trials made in this direction, especially those in which electricity is used.

Separate wires were drawn between the lamps, and small devices fixed, by means of which the valves could be opened and closed by the electric current, and at the same time the gas ignited, either by electric sparks, or platinum-black, or by a wire brought to red heat.

In course of time, however, many disadvantages showed themselves, such as: (1) The breaking of the wires by the weight of snow or some other cause; (2) entanglement with other wires, especially those of trolley lines; and (3) changes of temperature, etc., causing the oxidation of the contact-buttons, and otherwise influencing the small electric devices. In many of these instances, it is difficult to locate the defect which causes the interruption of the current. Putting the wires underground only increased the cost of installation, without improving the situation.

A second method was to light and extinguish by means of compressed air. This system has the disadvantage that leaks or obstructions in the small pipes to be used, and which have to be laid underground, would, until found, cause a great expense, and until repaired, would put quite a number of lamps out of use.

A third way to accomplish the desired end was tried with an apparatus influenced by the difference in the pressure of the gas; but it was found difficult to procure the required difference in a distance of many miles, especially where the pipes leading into the houses are connected with the same main and in towns where the streets are hilly. This system has failed altogether, as proved by an attempt made in Brussels to measure the gas consumed during the hours of day and night with one and the same meter.

A fourth method, using an hydraulic apparatus based upon the difference in the gas pressure or compressed air, proved a failure also on account of the evaporation of the fluid and the influence of cold.

Attempts have also been made in other directions.

There is, in the author's opinion, but one way to solve this problem, and that is by the use of some device whereby each lamp can be lighted and extinguished independently of the others, so that, in the event of a failure through any cause, one lamp only, and not a whole section, will be affected.

The Gas Engineers' Association of Switzerland had requested the author to show and explain such an apparatus made by the Actien-Gesellschaft für autom. Zünd und Löschapparate in Zurich, which Company has now, after experimenting for three years, brought it to such a perfection that it seems to answer all demands. This apparatus consists of a clockwork, of the very best quality, which cannot be influenced by changes of temperature. It is hermetically enclosed in a brass box, containing the valves (separated airtight from the movement to prevent gas escape and explosion), which are set in motion by the spring of the clock. The apparatus is placed in the centre of a wrought-iron support specially constructed, which can be fitted to every description of lantern. The whole has a neat appearance, and throws no shadow. The movement itself runs twenty days, but should be wound up every fortnight. Once within that time, at least, lamps have to be cleaned and the lighting-hours changed; so, without extra expense, the winding and time changing can be attended to by the lamp cleaner.

The advantages of this system are the following:—

(1) Each lamp can be lighted and extinguished separately and at any designated time.

(2) Any number can be lighted and extinguished together within a few minutes' time.

(3) The mantles of the Welsbach lights are better preserved, because the apparatus opens the valve gradually to let the air escape, thus preventing an explosion, and because the jar caused by the knocking of torches against the lamps is done away with.

(4) A great many lights can be extinguished about midnight. Some cities allow these to burn all night, because a third round on the part of the men would add more to their wages than the amount saved in the gas consumed.

The apparatus can be furnished in five different forms:—

(1) One with a simple stopcock.

(2) One with a regulating-cock, through which the lantern can also be lighted and extinguished at any time by turning the lever. This has also an arrangement with which the action of the movement can be detached, and is suitable for such towns as during moonlight or summer months suspend lighting altogether.

(3) One for lighting and extinguishing two to three flames together.

(4) One which will light two flames, and extinguish them singly, at different times.

(5) One which can light and extinguish twice within twenty-four hours.

By means of these different arrangements, it is not necessary to do away with any lanterns now in use, or employ help for such special lamps.

The apparatus is used in prominent cities like Zurich, Geneva, Lucerne, and Winterthur, over a thousand being in use or in course of erection.

The paper was accompanied by illustrations.

The Discussion was postponed until the following day (p. 292).

The meeting was then adjourned.

WEDNESDAY, 4th SEPTEMBER, 1901.

Mr. William Foulis, Vice-Chairman, in the Chair.

DISCUSSION ON MR. ROTHENBACH'S PAPER.

The Discussion was taken part in by Mr. J. L. Chapman, Mr. Charles Carpenter, Mr. T. Holgate, Mr. G. R. Love, and the Chairman.

Mr. A. Kilchmann replied on behalf of the author, to whom a vote of thanks was accorded.

"THE PRINCIPLES OF CONSTRUCTION OF A PROPOSED MODERN GASHOLDER FOR AMSTERDAM."

Paper by J. Van Rossum du Chattel.

Abstract.

The conditions for the construction were the following:—The capacity of the holder (to be erected on a very poor subsoil) should be 100,00 cubic metres, or about 3½ million cubic feet. Piles must be used to give the necessary stability. The diameter must be about 60 metres, or 200 feet. The piles must bear a maximum weight of 10 tons each, their normal length being 14 metres. The water level is 1½ metres below the level of the ground, where the holder is to be built. The indifferent nature of the ground, and the high cost of a good foundation, make it necessary to reduce as much as possible the total weight, and to exclude a tank made of brickwork or concrete.

Only a wrought iron or steel tank containing a minimum weight of water could, therefore, solve the problem. An ordinary tank, with a flat bottom for a four-lift holder, with a diameter of about 60 metres, would contain 29,000 tons of water; and with the holder weighing about 2000 tons, the total weight would be 31,000 tons. This shows that, with regard to economy in weight, it was necessary

to take into consideration the weight of the water. These difficulties, it was thought, could be met by the construction of a tank after the patent of Professor Intze, or by an annular tank above the ground. For the latter construction less material is required, and consequently it is cheaper and more desirable also from a general point of view. Care, of course, must be taken that no gas can enter into the interior space of the tank, which is intended to be used as a store room. It is therefore necessary that the inner roof of the tank or intervening central space should be covered with water.

In order to make this large store room suitable for heavy materials, it was so arranged that a locomotive and train could pass under the tank and the walls, the door openings being made sufficiently high.

This is, so far as the author knows, the largest annular tank ever constructed under these conditions, and the character of the soil and the vibrations induced by trains passing under the tank must be taken into consideration. The supposition that, due to the nature of the subsoil, the tank will sink at one side 20 centimetres, or about 8 inches, made the calculations very complicated.

If the tank sinks on one side more than 8 inches, means are provided to put it straight again with wedges; and these, it is clear, may also be used for a sinking of less than 8 inches. To prevent this sinking becoming more than 8 inches, 80 lifting apparatuses, put together under the stays, will come into action, after the tank has been emptied. Great care was taken with the foundation to avoid, so far as possible, the use of these contrivances. Testing piles clearly proved that the subsoil was of a varying character, and that the length of the piles at different places must vary between 40 and 60 feet. On the piles which are below the lowest water level a bed of concrete with old iron rails is built.

The wall on which the tank is to be erected will be made so that there are 40 door openings through which the train may pass. Moreover, these walls, instead of being made as thick as if a low stress was allowed, will be made of superior brickwork, with the best bricks set in Portland cement, so that a higher stress may be allowed. The calculations are for a pressure of about 250 kilogrammes per square metre; and for a maximum lateral strain on the bricks of 15 kilos. per square centimetre. The piles will bear a maximum weight of 7000 kilos. each. In order to render a turn table with radial rails possible in the centre of the store room under the tank, so that the waggons may be discharged in all directions, it was not desirable to have any support under the tank, or any centre pier. This problem was rather difficult to solve.

Instead of covering the intervening space or roof of the tank with a few inches of water, a larger quantity was used, 40 centimetres or about 16 inches depth of water resting on the cover. The weight of this water gives compound stresses on the 40 oblique struts, and, from these, on the 40 vertical stays of the inner mantle of the tank. The vertical stays give additional strength to meet the pressure of the water in the annular tank, so that a much lighter construction sufficed. The roof of the central space is made of sheet iron, resting on 40 radial horizontal beams, supported by the 40 vertical stays, these last serving also to support the curved plates and transmitting the water pressure from the roof to the annular space. To support the vertical stays struts run from the horizontal beams, and give, by their shearing force, an exterior bending stress. The 40 horizontal beams meet in a central ring or star, and the 40 rays of this star are joined by hinges to the beams. This construction simplifies the calculations; and this is desirable, as lateral compressions are to be expected on account of the nature of the subsoil. The principal dimensions, given in centimetres, are:—

Exterior diameter of tank	6130
Height	989
Width of the ring, as far as the front of the stay	215
Diameter as far as exterior of stays	5700
Height to the roof sheets	918
Total length of roof beams	5500
Height of stays to the beams	863
Distance from the face of the curved sheets to the front of stays	12

(The paper gives further an introduction to the investigations and calculations regarding the forces acting on each part of the structure.)

The calculations for the tank must take account of the following:—

1. In addition to the weight of material from which the holder and tank are constructed there is a uniform load of 60 centimetres of water.
2. The tank sinks 20 centimetres over one side, the whole gas-pressure working. In this case a uniform load of 50 centimetres of water, and a wedgewise load at one side zero, at the opposite of 20 centimetres of water, have to be considered.
3. The tank is filled, but without gas in the holder; and there is a uniform load of 40 centimetres of water on the cover or roof of the tank. This case has to be calculated separately, as some struts undergo the full pressure from the outside, but a much weaker bending and shearing pressure from the inside.

4. During the simultaneous filling of the roof and the annular space, the degree of filling must be found at which there is the maximum outward bending of the struts.

Of very great interest is the simultaneous filling of the cover of the central space and the annular tank. Both must be filled at the same time. The tank having a capacity of 4545 cubic metres, and the cover of 974 cubic metres, the rate of filling must be in the ratio of 4.67 to 1. The cover having two concentric spaces, the filling of both parts has to take place in proportion to the surfaces; that is as 1 : 8.4.

Special boxes with overflows, dividing the water in the required quantities are therefore made for the purpose. The same care has to be taken in emptying the tank.

Very important, also, is the construction of the hinge joints in the horizontal beams. The calculations show that they have to bear a vertical load of 6640 kilos.; and there is also a maximum horizontal force of 136,281 kilos.

The following members took part in the Discussion:—the Chairman, Mr. Charles Hunt, Mr. Charles Carpenter, and Mr. W. Wood.

The author replied, and a vote of thanks was accorded to him.

A correspondence has appeared in the technical press between Mr. F. S. Cripps and the author, and is reported in the proceedings.

"THE PRODUCTION OF ILLUMINATING GAS FROM COKE-OVENS."

Paper by F. SCHNIEWIND.

Abstract.

THIS paper describes the progress made in the United States and Canada in recovering illuminating gas from by-product coke ovens. It discusses its bearing upon the smoke problem of large cities, and gives particulars of various allusions to the subject in past literature. It deals with the fuel supply of large cities, and gives figures showing the comparative amounts of bituminous coal and anthracite coal used in some American cities for the year 1900.

It then gives a general description of the combined coke oven and gas process, compares it with ordinary gas retort practice, and gives a description of a plant of 100 coke ovens of the latest type of the United Coke and Gas Co., including the system of coal and coke handling, the arrangement of gas mains, the condensing plant, the treatment of the tar produced, and the methods adopted for the further enrichment of the rich gas by the benzole extracted from the poor gas.

It then proceeds to discuss the principles of the dry distillation of coal in coke ovens, and gives figures as to the yields of gas, tar and ammonia, etc., of various American coals in use. It details the quality of the gas made during the various periods of the coking process, and gives figures showing that the operating results approximate very closely to those obtained in the various tests made. The question of heat balance is then carefully discussed, and comparisons made of the heat distribution in products of distillation from Otto Hoffman Ovens, and ordinary gas retorts. The subject of the enriching of coke oven gas is then carefully discussed, and tables given showing the distribution of illuminants in international coal gas. The author then deals with the application of coke plants to the gas supply of large cities, and gives figures showing the approximate gas consumption of a city of 400,000 inhabitants supplied by a coke plant. The fluctuation in gas consumption is again introduced, and the methods of meeting it by means of auxiliary producer plants, auxiliary water gas plants, and combined blue water gas and producer plants are discussed.

The author concludes by claiming for the system serious con-

sideration in the solution of the smoke problem, and argues that it is capable of forming a central station for the supply of light, heat, and power.

The following members took part in the Discussion:—Mr. Livesey, the Chairman (Mr. Foulis), Mr. S. O. Stephenson, Dr. Révay, Mr. Charles Hunt, Mr. James Barrow, Mr. W. R. Herring, and Mr. W. W. Hutchinson.

Dr. Révay replied on behalf of the author, to whom a vote of thanks was accorded.

Dr. Schniewind has also replied by letter to the remarks on his paper, and Mr. Charles Hunt has sent a communication.

"THE DESTRUCTION OF GAS PIPES BY MEANS OF ELECTRICITY."

Paper by W. LEYBOLD.

Abstract.

THE author gives the durability of the pipes used for the distribution of gas in towns as from 25 to 50 years. He states that there are certain influences sometimes at work which may considerably shorten their lifetime. A new danger has, however, been introduced through the construction of electric tram lines—viz., electrolysis. In Germany the electric current passes into the wires from the generating stations at a pressure of about 500 volts, and returns to the station by means of the rails. As the rails give a certain resistance, part of the current will pass through the earth into the gas and water pipes. The author took steps to discover whether in any pipes, near which any electric tram lines ran, the electric current was in existence, and he found that in water pipes laid at a distance of 6 kilometres from the nearest electric station considerable tensions were found; and this was also the case in gas pipes in the town at night when no electric trams were running. This is accounted for by the theory that the cast iron pipes, with lead as the jointing metal, lying in the damp ground, produce a galvanic action. When the tram lines were working the tension in the pipes varied from 0.2 to 1 volt to as much as 4.65 volts near the generating station. All the electricity was supplied from one works, the working line being 100 kilometres long, and the annual consumption of current 13 million kilowatt hours.

It is known that, by the electric current in the presence of saline solutions, metals can easily be dissolved. The ground in Hamburg contains small quantities of chloride of sodium, to the extent of 0.006 to 0.04 per cent.; the electric tramway authorities also use salt, etc., for melting the snow in winter time; this affords, therefore, an opportunity for the eating up of iron in the earth by the electric current in the presence of the solution of salt.

In April, 1899, an escape of gas was found in a street near the electricity works, at a spot where the cars pass at intervals of three minutes, there being two lines of tramway rails. On investigation, it was found that the service pipes passing at right angles beneath the rails were corroded immediately underneath them, penetration being discovered in nearly every case. The pipes were covered with canvas soaked in boiled tar. In many cases blisters were found between the iron and the tar, which were filled up with a green

solution, protochloride of iron, and it was inferred that the wrapping of boiled tar and canvas favours the destruction. The pipes were taken up and replaced with others, but after the expiration of seven to eight months the destruction again showed itself as before.

The importance of great care being taken to reduce the currents passing into the pipes is emphasised, and various methods are mentioned for securing this result. The rails should be of high conductivity, with sufficient transverse section, and with the points of contact well joined together by soldered copper wire. The use of thermite is also recommended, as is also the fixing of insulated return transmission cables in many places for the carrying of the current back to the works. This has been done in Hamburg, with the result that the tension existing in the gas pipes has been reduced to 0.45 volts. The cast-iron pipes in the town have not been perceptibly affected. Allusion is made to electrolytic damage done to pipes at Erfurt; and this, it is stated, was principally due to the rails used for the tramway being too light for the purpose.

Mention is made of the rules for the protection of gas and water pipes drawn up by the German Electrical Technical Association, particulars of which are to be published shortly. The author gives it as his opinion that gas and water works have a right to demand that the Electric Authorities should do everything in their power to protect the pipes.

Mr. Livesey at this point again took the Chair and opened the Discussion. The following members also took part in it:—Mr. James Mansergh, President of the Congress, Mr. Charles Carpenter, Mr. S. O. Stephenson, Mr. W. R. Herring, Mr. T. Holgate, Mr. S. Meunier, Mr. Gisbert Kapp, Mr. Helps, and Mr. Foulis.

The author replied, and a vote of thanks was accorded to him.

The meeting was then adjourned.

THURSDAY, 5th SEPTEMBER, 1901.

Mr. WILLIAM FOULIS, Vice-Chairman, in the Chair.

"APPLICATION OF THE UNIT SYSTEM OF GAS MANUFACTURE TO ITS PURIFICATION."

Paper by CHARLES CARPENTER.

Abstract.

THIS paper discusses the close proportioning of output to requirements afforded by the Retort method of manufacture. Each retort or unit is independent, and, alone or coupled, would give, when heated and charged, its maximum duty in thermal feet.

The question of a group of retorts in settings is discussed; and a table, drawn up for a plant for a works having a maximum output of five million cubic feet per day, shows the relation between the gas made and the number of settings at work when the settings are groups of 6, 8, 9, and 10 retorts. The purification plant is then considered, and the tables drawn up for a five million cubic feet works using—

I. Two tower scrubbers, 20 feet diameter, 70 feet high, 314 square feet area, 21,980 cubic feet contents, and wetted surface 527,788 square feet; and

II. Standard washer, 8 feet outlet diameter, 4 feet inlet diameter, 12 inches wide, 37 plates, each 0.028 inches thick, per wheel, and wetted surface per machine of 12 wheels 24,672 square feet.

	Millions per diem.	Total area, sq. ft. per million.	Gas area, sq. ft. per million.	Wetted surface, sq. ft. per million.
Tower Scrubbers.	5	63	47	105,557
	4	78	59	131,947
	3	105	79	175,929
	2	157	118	263,894
Standard Washers.	5	8·6	2·7	4,934
	4	10·7	3·4	6,168
	3	14·3	4·5	8,224
	2	21·5	6·8	12,336

The second column shows the very striking difference of practice in the two types of vessels. It appeared worth while to try the experiment of combining to as great an extent as possible the advantages of both. A pair of towers were therefore constructed for a works having a two-million winter and a one-million summer load. Each tower was made 2½ feet square by 26 feet high and packed with iron "bundles" built up similarly to those used in the "Standard" machines, but rectangular in shape. Each bundle is 9 inches by 10 inches by 30 inches by 0.036 inch, set in tiers supported upon strips cast on opposite sides of the tower. Three

	Millions per diem.	Total area, sq. ft. per million.	Gas area, sq. ft. per million.	Wetted surface, sq. ft. per million.
Tower Washer.	2	3·1	2·6	6·075
	1	6·2	5·1	12·150

sides of the tower are permanently bolted together, the front or fourth side being of separate plates with distance pieces, so that it can be stripped from top to bottom. The whole of the bundles, if necessary, can be removed and fresh ones substituted in an ordinary working day.

The construction is so simple as to readily lend itself to the design of a machine wherein, under varying conditions of gas production, a more constant ratio of scrubbing surface and gas treated can be obtained. For instance, in the case of a five million cubic feet works two rectangular vessels, 7 feet 6 inches by 2 feet 6 inches, divided vertically by two partitions running from top to bottom, or one, 7 feet 6 inches by 5 feet, divided into six vertical chambers, would provide all that appears necessary. Both liquor and water could be used in one, two, or three chambers, according as either was used for the make required. The additional advantages are small ground-space required, absence of motive power, and facility for cleaning. The liquor and water are distributed by shallow perforated trays; but Barker mills, with or without circular tops, could be used if preferred.

The proportioning of plant area to make of gas suggested in the case of scrubbers can likewise be applied to purifiers. The minimum area recommended may be taken at 400 feet super per million feet of gas per diem. A table is given showing the calculated size of the purifiers in the case of the typical works selected.

It is easy, by the addition of diaphragms, to divide up, into any number of sections, the purifier; from the main inlet valve of which connections, with controlling valves, would branch off into each compartment. The proper rate of flow and time of contact could be given as between gas and material, independently of the volume of gas being produced. Such a set of purifiers has been put into operation at the South Metropolitan Gas Company's works; and, although the experiment is in its infancy, there is no doubt that the purifying material is more easily acted upon than is the case with the other vessels.

In conclusion, the author advocated an endeavour being made to fix the best condition for speed of contact and area in the purifying plant of gas works, and then to provide means whereby this may be obtained in regular working within the extreme limits of production.

The discussion was taken part in by Mr. Charles Hunt, Mr. S. Y. Shoubridge, Mr. G. R. Hislop, Mr. H. E. Jones, Mr. A. Wilson, Mr. J. W. Helps, and the Chairman; and the author replied.

A vote of thanks was accorded to the author.

"THE MECHANICAL TRANSPORT OF MATERIALS IN GAS WORKS."

Paper by WILLIAM REGINALD CHESTER.

Abstract.

THE author confines his remarks to a description of the apparatus he has found most applicable to gasworks use, to the measure of its capacity in relation to the original cost of the installation, and to the cost of its maintenance and upkeep. The materials principally dealt with are coal, coke, breeze, ashes, purifying material, and sulphate of amonia, the manipulation of most of which is continuous throughout the twenty-four hours.

Figures are given relating to the cost and performance of an installation.

COAL TRANSPORT.

The apparatus used in coal transport may be divided into three types—viz., the inclined elevator, the horizontal push-plate conveyor, and the horizontal band conveyor.

Elevators.—The coal elevators are used for raising the coal from the breakers, and conveying it into overhead hoppers. They are fixed at an incline of 50 degrees, and their total length is 74 feet each. They have been in use for 5 or 6 years. Each bucket has a capacity of about 870 cubic inches, and is worked at a speed of 140 ft. per min., the normal capacity being about 30 tons per hour. Five of these elevators have transported 335,237 tons of coal, at a cost 0.061d. per ton for repairs. The original cost of the elevators was £4 4s. per lineal foot of traverse.

Push-Plate Conveyors.—The push-plate conveyors receive the coal at the top of the elevators and carry it forward. The plates work in a steel trough 20 inches wide, having hinged doors at the bottom. The speed of traverse is about 180 feet per minute, and the working capacity about 40 tons per hour. For a total weight of coal conveyed, 36,536 tons, the cost for repairs was 0.039d. per ton; the original cost was £6 7s. 4d. per lineal foot run.

Band Conveyors.—Band conveyors are used for conveying the coal across the retort-stack; each of the four in use has a traverse of 30 feet. The belt is cotton canvas, 18 inches wide, and it runs on cast-iron rollers at 250 feet per minute, with a carrying capacity of 40 tons per hour. For a total weight conveyed of 149,350 tons, the cost of repairs so far has been 0.113d. per ton. The original cost was £2 9s. 4d. per lineal foot of traverse.

COKE TRANSPORT.

The apparatus may be divided into four types—viz., the inclined elevator, horizontal hot coke conveyors, plate belt conveyors, and canvas belt conveyors.

Elevators.—Coke elevators receive the coke from the horizontal conveyors and carry it into overhead storage hoppers. The buckets are larger than the coal elevators, and are spaced 18 inches apart; each has a capacity of 1150 cubic inches, and a speed of 140 feet per minute. The normal capacity is about 20 tons per hour, and for a total of 178,541 tons of coke transported the cost for repairs is 0.913d. per ton. The first cost of the elevators was about £6 6s. per foot of traverse.

Push-Plate Conveyors for Hot Coke.—Three push-plate conveyors for hot coke are in use, two carrying coke as drawn from the retorts to the foot of the elevators, and a third carrying the coke from the elevator head. The push-plates are of malleable iron, spaced 24 inches apart. The speed of traverse is about 48 feet per minute, and the working capacity 20 tons per hour. For a total of 9923 tons of coke transported the cost for repairs is 0.891d. per ton; and the first cost of the apparatus £5 3s. 11d. per foot run.

Plate Belt Conveyor.—Five plate belt conveyors are also used for conveying the coke from the retorts to the foot of the elevator; the belts are of flat steel plates, overlapping at the ends, and are continuous. The speed of traverse is 42½ feet per minute, and the working capacity about 30 tons per hour. During six years they have conveyed 149,350 tons of coke, at a cost for renewals of 3.714d. per ton. The first cost was £3 12s. 6d. per foot run, the difference between this and the previous system being accounted for by the fact that the plate belt conveyor has been completely renewed once, while the push-plate conveyor has not been long enough in use to require this.

Canvas Band Conveyor.—A canvas band conveyor is used for carrying small coke and dust which pass through the screens from the hoppers to carts, etc. The belt is 17 inches wide, with a speed of 135 feet per minute, and a capacity of about 20 tons per hour. It has conveyed 10,000 tons of small coke, at a cost for renewals of 1d. per ton, the original cost being £4 10s. per foot run.

PURIFYING MATERIAL TRANSPORT.

The apparatus consists of two inclined elevators with buckets; they have a traverse of 40 feet, and a capacity of 10 tons per hour, at a speed of 80 feet per minute. They have transported 37,685 tons of material, at a cost of 0.046d. per ton for repairs. The total cost was £5 7s. per lineal foot run.

SULPHATE OF AMMONIA TRANSPORT.

The apparatus used has an indiarubber belt, 110 feet long and 17 inches wide, running on rollers at a speed of 140 feet per minute. It has carried 2180 tons at a cost for repairs of 4.63d. per ton. The original cost of the apparatus worked out at £1 11s. 3d. per lineal foot.

The following members took part in the Discussion:—Mr. S. Y. Shoubridge, Mr. Charles Hunt, Mr. W. Foulis, and Mr. T. Holgate.

The author replied, and a vote of thanks was accorded to him.

"THE CONSTRUCTION OF INCLINED RETORT CARBONISING PLANTS."

Paper by WALTER RALPH HERRING.

Abstract.

THE primary object of the process described in the paper is the reduction to a minimum of the labour hitherto involved in the charging and drawing of coal-gas retorts, by employing simple and reliable mechanical devices for manipulating the material to be dealt with, and by taking the fullest advantage of the natural force of gravity to charge and draw the retorts when set upon a plane inclined to the horizontal line. There are other secondary advantages, such as the greater producing capacity over a given area of land, and economy in construction, etc.

Considerable variety is shown in the outward form of the different plants existing in this country, as contrasted with the various installations upon the Continent of Europe. A great uniformity is discernible in the Continental installations, owing probably to the fact that, with few exceptions, the plants have been erected by the same constructors. Another distinctive feature of Continental installations is the length of the retort. The British practice may be said to be 20-feet retorts, where space permits of their adoption; whereas, on the Continent, from 3 to 3½ metres (10 feet to 11 feet 6 inches) is the predominant length of the retort. The only installation in this country, of which the author has any knowledge, approaching the Continental length is one which was erected at Leigh, in Lancashire, where 12 feet 6 inches retorts were put in. This bench, however, was levelled to the ground, and reconstructed as 20-feet retorts, some few years after its first introduction.

The author, in his erections at Huddersfield, put in 15-feet retorts, the available space not permitting of anything longer. The fact of the majority of the British installations being 20 feet is, however, in the author's opinion, sufficient to prove that there can be no doubt as to their efficacy, and also their utility. The increased capacity of the hoppers necessitates but a small percentage in the additional weight of their structure; and, from a labour point of view, the operation of charging a 20-feet retort with 7 cwt. of coal is no greater, and occupies but a few seconds more than the charging of a retort from 12 feet 6 inches to 13 feet long.

The inclined retort installations at the present time may, broadly speaking, be defined as consisting of two distinct types. The best known type is that having continuous coal-storage hoppers (subdivided or not) erected above the benches, with or without measuring chambers beneath, but more commonly with the measuring chamber attached to the underside of the storage hopper. The other distinctive type has one or more coal storage hoppers centralised, the charging shoot forming also the measuring chamber, receiving its charge from beneath the hopper, and traversing with it to the retorts to be charged. The author throughout has been a staunch advocate for the continuous storage hopper, with or without the measuring chamber beneath. The same weight of coal must be stored in either system, and the greater the bulk stored over a given area, the greater strength is required in the construction of the hopper and its supporting structure. Continuous hoppers need not be more than ¼ inch thick, properly stayed, extending continuously for the length of the retort bench, with the measuring chambers suspended beneath them.

The charging appliances have a most important influence upon the successful working of the system. The many varieties of coal that have to be dealt with have brought into existence all sorts of devices whereby the charge can be regulated so as to flow into the retorts at a uniform speed, and ensure a perfectly level and uniform charge throughout the length of the retort.

Generally speaking, in the case of type A—viz., the continuous hopper system—the coal is allowed to drop from the base of the measuring chamber, and is checked in its descent by the adjustable sloping valves or balanced flaps within the charging shoot. The traversing charging shoot working in conjunction with the centralised hopper, or type B, has first to be charged from the hopper, and has then to carry its charge to the retort, where it discharges from its base on to the mouth of the retort. The base of the shoot is set approximately at the angle at which the retorts are set, a valve is opened, and the coal, by its natural inclination, slides into the retort. Coals having differing physical characteristics will act differently under these fixed circumstances of angle of discharge; and as there is no positive power existing with this appliance, it is not surprising that it is now being regarded as of doubtful utility as a charging appliance.

Details of the construction of the charging shoot were given and mention was made of the necessity for controlling the area of the aperture through which the coal discharges from the overhead tank or measuring chamber. Dealing with the question of the automatic discharge of the coke from the retorts, the author remarked that during the life of a setting not more than 50 per cent. of the retorts could be depended upon to discharge themselves without some assistance. Tapered retorts had been introduced to facilitate the discharge of the carbonised fuel. It is important that the cross-section of the retort should be properly designed, so as to permit of the coal in the retort, during the process of coking, rising or expanding freely without jamming itself in the arch or crown of the retort, the cross section being preferably a flat base with the sides opening outwards before the curve of the retort is commenced.

The author suggested the introduction of simple mechanical means, worked from the upper end of the retorts, to assist in discharge, dealt with the manipulation of the slides or valves of measuring chambers and overhead hoppers, and laid before the meeting particulars of a small double-acting hydraulic cylinder which he had introduced at Edinburgh.

He then referred to the simplifications in the structural ironwork of inclined retort installations, traversing screens for projecting the coke and tar clear of the mouthpieces, and the improvements that had recently been made in the construction of hot coke conveyors.

In conclusion the author gave a long description, illustrated by numerous diagrams, of the 1000 tons per day inclined retort plant now being erected at the new Edinburgh gasworks from his designs, laying particular stress upon the method of heating the furnaces, the means of discharging the coal from wagons, the feeding of the coal breakers, elevators, conveyors, etc., and the handling of the coke after carbonisation.

The following members took part in the Discussion:—Dr. Leybold, Mr. A. F. Wilson, Mr. F. W. Cross, Mr. Livesey, Mr. A. W. Onslow, Mr. G. Helps, Mr. S. Y. Shoubridge, Mr. Charles Hawksley, and the Chairman.

The author replied, and a vote of thanks was accorded to him.

A communication was received from Mr. C. E. Brackenbury.

Mr. Foulis proposed, and Mr. W. R. Herring seconded, a vote of thanks to the University Authorities for so kindly placing the College buildings at the disposal of the Congress.

The motion was unanimously carried.

Mr. Charles Hunt proposed, and Mr. John West seconded, a vote of thanks to authors for their papers.

Mr. William King proposed, and Mr. J. Hepworth seconded, a vote of thanks to the Chairman and Vice-Chairmen.

The Chairman and Mr. Foulis replied.

The Chairman proposed, and Mr. Foulis seconded, a vote of thanks to Mr. Helps for the manner in which he had performed the duties of Honorary Secretary to the Section.

The proceedings then terminated, and the business of the Section was brought to a close.

SUMMARY OF PROCEEDINGS

OF

Section IX.—Electrical.*

TUESDAY, 3rd SEPTEMBER, 1901.

W. LANGDON, Chairman, in the Chair.

INTRODUCTORY ADDRESS.

By W. LANGDON, Chairman.

EXTRACTS.

IN the course of his address the Chairman said:—"Just fifty years since London, under the auspices of the nation's lamented Prince Albert, gave birth to the first International Exhibition. Followed by numerous others, at home and abroad, none, it is pleasing to note, have proved more successful financially, or more fully met the object for which they were established, than those inaugurated by the enterprise of Glasgow's citizens—the last and most successful of which forms one of the attractions incidental to the assemblage of this Congress and of the inauguration of the new century.

There can be no question that the result of these great undertakings has been for good; that they have been a stimulus to manufacture and trade; and that—greatly beyond all else—they have been a means making for peace. Whether we, as a nation, have been the gainer or the loser, the world has richly reaped. Exhibitions, railways, steam-boats, education, the ready intercourse between peoples, have told, and are daily telling their tale. Few articles remain the privileged product of any one place.

Manufacture has become cosmopolitan, and the rivalry of the

* The full Proceedings of Section IX., being part 153, Vol. XXXI., 1901, of the Journal of the Institution of Electrical Engineers, are published by The Institution of Electrical Engineers, 28 Victoria Street, Westminster, London, S.W., price 5s., post free.

future between the most advanced nations of the earth will be that of manufacture—the power to apply the products of the earth to the exigencies of life at the least cost, and with the least loss of time.

The supremacy of a nation may be attained by force of arms, but war cannot be carried on without the sinews of war, and the sinews of war means the wealth of the nation. Whence comes this national wealth? Surely by the industry and intelligence of its people—the power to observe, to apply, and to produce.

Lord Rosebery, when speaking recently at the Mansion House, remarked "we are coming to a time of stress and competition, for which it is necessary that we should be prepared," and later on he observes, "It is necessary for a nation in these days to train itself by every valuable method to meet the stress and the competition that is before us."

The question whether England, in comparison with other nations, is becoming retrograde in her industrial achievements must prove one of peculiar interest to all who seek this country's welfare. There are grave reasons to fear that in some parts, especially in the more modern applications of science, and notably in that development with which the Institution of Electrical Engineers is so closely allied, we have not retained that prominent position which has characterised this country for so long a period.

Twenty years back, British manufacture stood on level ground with other countries in the production of electrical machinery, yet, if we may judge by the following figures, for which I am indebted to Mr. Philip Dawson, it would appear that we have from some cause failed to meet even our home demands. From these figures, which are approximate, it appears that of some 300,000 indicated horse-power of steam engines laid down for lighting and traction, 73,000 have been imported from the United States of America; and that, of some 200,000 kilowatt capacity of generators, 71,000 were derived from the same source. It will be understood that this does not mean that the residue was British production.

It is not my intention, nor would the time at my disposal admit of my attempting to enter into details why this is so. I take the bald fact as illustrated by the figures I have quoted. England did not meet the demand! Can it be that the British manufacturer lacked confidence in the permanency of this new electrical development? I quote again from Mr. Dawson. The capital invested in European countries and the United States in electric lighting, power, and traction works, amounts to £367,000,000. Of this sum the United States contributes £200,000,000 and Great Britain £35,000,000. The number of miles of single track equipped for electric traction in the two countries is, relatively, 21,000 and 900: of motor cars, 68,000 and 2600. Germany, where the power employed for lighting work approaches closely that of England, has 2300 miles of track, and 5400 cars, although the invested capital is but twenty-nine millions, as against England's thirty-five millions for an enormously less mileage and smaller equipment.

The population of Great Britain is approximately 40,000,000 as against 70,000,000, that of the United States. The area in square miles is, relatively, 121,115, and 3,581,885. Too much stress must not be laid upon territorial comparison, although it would seem an evident corollary that the more dense the population the greater must be the demand for means of locomotion.

These figures, should, at all events, prove effectual in disposing of any doubt that electrical development is stable. That it is only at the beginning of its era, and that an enormous field lies before it in almost every path of commercial and social life, must be evident to every observant person. It is not, however, with its utility that I desire to deal so much as with the means for its production: the production by our own country of all that is needed to meet not merely the wants of our home demand but that of our colonies as well.

Two important factors—cost and promptitude of delivery—attend successful competition in manufacture. Inspired with confidence in the future of electrical work, with, as it were, a prescience of those demands which must arise, and unencumbered with many of those restrictions and regulations which attend similar undertakings in England, other nations have seen and have seized their opportunity, gained experience, standardised their productions, aud have thus, in advance of this country, prepared to meet any ordinary demand that may arise.

Cost depends much upon our labour conditions. Within a very short period rivalry in manufacture will be far more acute than is even now the case, and in it labour will play the chief part. America, as well as England, has her labour troubles. Trade Unions exist there as well as here, but the principles which govern them differ from those which prevail here. There the man works unrestricted, with all his might. Of what avail is education to the child if manhood fails to take full advantage of it? In the following comment of the *New York Sun* we have an expression of opinion that may well be laid to heart: "When the British workman is willing really to work for his wages, then, and not till then, Great Britain may hope to survive in the great revolution which has begun to sweep through the modern economic world. There is no indication that that willingness will be shown until the bitterness of dire adversity has wrung it from the misguided Labour Unions of Great Britain."

The artisan should not lose sight of the fact that this question of cost is one which affects the employé as well as the employer. In the long run the master may be thrust to the wall. He may spend his last penny in keeping his works going, but when he closes those works the workman's means of livelihood are also, so far as the industry there dealt with affects him, closed. Unhappily, identity of interest, so necessary to both master and man, is more frequently marked by its absence than its presence. Until the employé can be induced to recognise in a practical manner the fact that his employer's interest is also his interest, those labour regulations which have been fruitful of so much harm to the manufacturing interests of this country, and which must in the end prove disastrous to the workman, will continue. So long as the production of a certain commodity is peculiar to a given locality, the question of cost is not so material; but where its production is world-wide, labour conditions must subscribe to those obtaining elsewhere, otherwise the market for that commodity will be lost.

We are speedily approaching a condition in the industrial progress of the world that will test to the utmost, not merely our means of production and our skill, but our position as a nation; for the pre-eminence of a nation will in future be largely determined by its progress in manufacture, and from it mainly shall we have to look for the means by which the nation's power will be maintained. A people may trade. Articles may be bought and sold, but food for the worker lies not there. The wealth of a land is to be found in that which it produces—whether from the soil or by the handicraft of its citizens."

On the motion of Professor M. Maclean the Chairman was thanked for his address, and on the motion of the Chairman Professor Gray was thanked for placing his rooms at the disposal of the Section.

"NOTES ON SOME OF THE CHIEF OBJECTS OF INTEREST TO ELECTRICAL ENGINEERS IN THE GLASGOW INTERNATIONAL EXHIBITION, 1901."

Paper by W. B. Sayers.

Abstract.

The paper deals with the plant, etc., under the following heads:—

1. Generating and Transforming Plant and Instruments in Use Therewith.

The Generating Station of the Exhibition.

The plant in the Machinery Section constituting the generating station for the supply of electricity to the Exhibition on the 500-volt continuous-current three-wire system (250 volts a side) was situated at the south end of the machinery hall and consisted of the following:—

Six Water Tube Boilers:

Two of	1000	I.H.P.	Babcock land type with chain grates.
One of	800	,,	,, Marine type hand-fired.
Two of	1000	,,	Stirling type, one with Vickers stokers and the other gas- or hand-fired.
One of	600	,,	Davey Paxman, with special super-heater.

One of the Stirling boilers was fitted for either coal or gas firing, and was at that time gas-fired, the gas being supplied from a Mason's gas-producer situated at the back of the boiler-house. Weir's and Worthington's pumps were feeding the boilers through Royal's and Berriman's heaters and Kennedy's water meters, the boiler steam-pressure being 175 lbs.

THE GENERATING SETS WERE AS FOLLOWS:—

NO.	ENGINE.	I.H.P.	GENERATOR.				
1.	Willans and Crompton	1200	Multipolar	compound,	1350	amps, at	500 v.
2.	British Schuckert ...	,,	,,	,,	,,	,,	,,
3.	Robey & Mavor & Coulson	500	,,	shunt ...	700	,,	,,
4.	Davey Paxman & E.C.C.	500	,,	compound,	570	,,	,,
5.	Belliss & Bruce Peebles	400	,,	,,	380	,,	,,
6.	Ernest Scott & Mountain	250	,,	shunt ...	760	,,	250 v.

7. Alley & Maclellan & Mavor & Coulson	400	Multipolar shunt	... 680 amps. at 250 v.
8. Browett Lindley & Ediswan	250	,, ,,	525 ,, ,,
9. Sisson & Clark Chapman	150	Two-pole shunt	... 320 ,, ,,
10. Robey, & Scott & Mountain	150	Multipolar shunt	... 250 ,, ,,
11. Ruston Procter ...	150	Two-pole compound	... 370 ,, ,,
12. Robey, & Scott & Mountain	150	Two-pole shunt	... 200 ,, ,,

Other plant included a balancer by Messrs. Bruce Peebles, and a three-phase plant by The Lancashire Dynamo and Motor Co. and Messrs. Hick Hargreaves.

The main switchboard was connected by telephones with all sub-boards.

The conductors for arc lights in the grounds were of aluminium.

Descriptions are given of the Olivetti direct-reading recording Wattmeter, Kelvin & James White "feeder log," and the Ferguson automatic overload switch.

Descriptions are also given of some of the Private Exhibits in Group I., including:—

Transforming plant by the British Schuckert Co.; generating set by Bruce Peebles & Co., with Belliss engine; plant for 5000-volt three-phase transmission by Hick Hargreaves & Co. and the Lancashire Dynamo and Motor Co., Limited; 800-kw. dynamo by Mather & Platt, Limited; and a 350-kw. slow-speed generator by Mavor & Coulson, Limited, with a Robey horizontal slow-speed engine.

2. Gas, Oil, and Coal-Dust Engines.

The author describes the Westinghouse three-cylinder gas engine (125 B.H.P., 260 revolutions per minute) exhibited by the British Westinghouse Co.; a 20-B.H.P. Diesel oil engine made by Messrs. Scott & Hodgson; and a M'Callum's coal-dust burning engine made by Messrs. D. Stewart & Co.

3. Electric Traction.

Reference is made to the exhibits of the British Schuckert Co., including a surface-contact tramcar system and electric locomotives; to a railway circuit-breaker and an electric tramcar exhibited by the British Westinghouse Co.; and to Messrs. Dick Kerr & Co.'s exhibits, including a tramcar generator and controllers.

4. Controllers, Starting Switches, and Starting Rheostats.

Messrs. Lahmeyer & Co. showed a controller for overhead travellers; and among the exhibits of the Sturtevant Engineering

Co. were motor starting switches, a multipole-switch starting rheostat, and a self-starting switch for motors. These are described.

5. Sundry Applications of Electricity.

The apparatus described in the paper included—

(a) Electric clocks by Messrs. Barr & Stroud.

(b) Drilling machines with magnetic adhesive foot by Mather & Platt, Limited.

(c) Mining machinery, electric haulage, and rock drills by the British Schuckert Co.; coal cutting machine by Clark Stevenson & Co.; Hurd's coal cutter and a ship deck planer by Mavor & Coulson, Limited.

(d) Motors. Selig Sonnenthal & Co. showed the Stow Manufacturing Co.'s motor with flexible shaft.

(e) Overhead conveyor for goods or luggage in railway stations by Mather & Platt, Limited.

(f) A Hoe printing press, electrically-driven, exhibited by The "Glasgow Herald."

(g) Pumping. 615-H.P. pumping plant by the British Schuckert Co.; an electrically-driven feed pump by Mather & Platt, Limited; and a centrifugal pump by Mavor & Coulson, Limited.

(h) A search light (150 amperes) by the British Schuckert Co.

6. Telephones.

The Glasgow Corporation showed a switchboard adapted for 400 metallic circuit lines (made by the Telegraph Manufacturing Co.) and operating 969 subscribers and 15 junction lines. The system of switching is the "Bennett M'Lean."

The National Telephone Co. also exhibited an exchange connecting 110 exhibitors.

7. Miscellaneous.

R. G. Ross & Sons showed Ross's speed reduction gear, and the British Westinghouse Co. showed experiments with a revolving (two-phase) field.

On the motion of the Chairman a vote of thanks was accorded to Mr. Sayers.

The meeting was then adjourned.

WEDNESDAY, 4th SEPTEMBER, 1901.

W. LANGDON, Chairman, in the Chair.

"HIGH SPEED RAILWAY CAR OF THE ALLGEMEINE ELECTRICITÄTS GESELLSCHAFT, BERLIN."

Paper by O. LASCHE.

Abstract.

THE car described in the paper is now finished, and, so far as trials and tests in the factory can give an indication of its behaviour under working conditions, has answered all expectations. It was tested at a peripheral speed of the wheels of about 56 metres per second, corresponding to a car speed of 200 to 210 kilometres per hour, and has been shown to the technical experts of the Studiengesellschaft für Elektrische Schnellbahnen prior to its transference to the experimental line.

I.—EXPERIMENTAL LINE.

The Studiengesellschaft was formed for the purpose of studying the technical and economical requirements of electric driving on long distance railways. The maximum limit of speed for the trials determined upon was 200 km. per hour. After careful consideration, it was decided to use an existing military line from Berlin to Zossen, placed by the German Military Department at the disposal of the Association, as the construction of a special experimental line would have involved a serious loss of time and much extra expense. The line selected is specially suitable, as it can be used for tests of the relative merits of different types of permanent way, track beds, rail profiles, and rail joints.

The present paper relates exclusively to the construction and testing of the car, and to investigations and experiments in connection therewith. The running tests on the line will shortly commence, and will, it is hoped, form the basis for future practice in two completely different senses.

(a) *Attainment of a Speed of 80 to 100 km. per hour.*—In the first instance, it is necessary to ascertain what speed is attainable without necessitating alterations in the existing line. Then the extent of the diminution in the wear and tear of the track must be determined when electric cars are used, as compared with that caused by steam locomotives running at the same speed. In many cases it is probable that the electrical working of a line with single motor-cars will enable existing bridges and tracks to meet the requirements of rapidly increasing traffic, whereas the use of heavier steam locomotives or longer trains would necessitate alterations. The attainment of these speeds would, in itself, be regarded as satisfactory, for distances would be covered in a reasonable time, and the public would have a more frequent train service, with shorter trains, instead of being provided with a few long trains in the day. The absence of smoke is a point in favour of electric trains. The construction of motor cars presents no difficulty, and no special alterations, either of the track, or signalling arrangement, or of the ordinary working conditions, are required for an electrical service. It is not, however, necessary, that electric traction should be more economical than steam traction; it will in many cases be sufficient to ensure its adoption to prove that the public will find it more agreeable, and that the general arrangements meet the requirements of the age.

(b) *Attainment of a Speed of 200 km. per hour.*—The experiments will be continued in the direction of determining the best working conditions for running at high speeds, the limits of which can only be ascertained by trial. For such high speeds as are here contemplated, the present systems of signalling might have to be altered, and the crossings and switches abandoned. It will be absolutely necessary to establish all high speed service on a separate track, with special lines in either direction, exclusively for this service. Lines for local and goods traffic must be built separately. The investigations to be made relate to the motor cars, the construction of the track, and the necessity for ensuring safety.

II.—THE CONSTRUCTION OF THE MOTOR CAR.

The motors are attached to the car itself, and no separate locomotive is used. Each car will accommodate about 50 passengers. The motors have in all a normal output of 1000 H.P., and a maximum output of 3000 H.P. The tests will show whether so much power is really necessary, and will indicate the consumption of power at different speeds, and under the influence of head or side winds.

For the working of long distance railways, the three-phase alternate current system could alone be considered. The generation and transmission of three-phase currents at from 40,000 to 50,000 volts pressure present no difficulty, but on the experimental line the pressure will be only 12,000 volts, the current being supplied from the central generating station of the Berlin Electricity Works, which is situated at a distance of 12½ km. from the commencement of the line. The length of the line is 24 km.

At present, transformers are placed on the car itself to transform the current down from 12,000 to 400 volts; but it is still undecided whether, in practice, it may not be better to use motors of medium voltage, say of 3000 volts, taking the current at this pressure from the line, to which it is supplied through transformers placed in transformer houses at definite intervals along the track. In this case the transformers would reduce the pressure from 50,000 to 3000 volts. It is well known that static transformers require no attendance as compared with rotary transformers.

The car is provided with a driver's platform at either end, from which the control is effected. All parts carrying current are placed in a special apparatus compartment, which is separated from the rest of the car by a double sheet-iron partition, so that passengers and attendants cannot come into contact with current at dangerous pressures. The total length of the car is about 22 m., and in cross-section it conforms to the standard structure of the German State Railway carriages. The car body is carried by two bogies, each with three axles, of which the centre is only a running axle, whilst each of the others carries a 250 H.P. motor, capable of developing a maximum of 750 H.P. The diameter of the car wheels is 1250 mm., and the speed about 960 revolutions per minute.

III.—INVESTIGATIONS WITH REFERENCE TO THE CONSTRUCTION OF THE MOTOR CAR.

The problem before the designer was the creation of something altogether new—namely, the construction of an experimental motor car, without reference to any existing type either of low speed electric locomotive or of street railway cars. The sole aim in the investigation was the construction of a motor car to run long distances at the highest possible speed.

The weight of the Electrical Equipment was, in the first instance, not less than 50 tons for the required output of 3000 H.P., but, by modifying the construction of the starting apparatus, motors, and transformers, the weight was reduced to 30 tons; but of this weight a large proportion was due to the transformers, which may possibly be dispensed with altogether hereafter.

The mechanical connection between the motors and the axles of the wheels was a matter of the greatest importance, the use of intermediate gearing being out of the question on account of the wear and tear to which it would be subjected. Although from the first the object was to obtain an elastic coupling, various designs and devices were tried, in some of which the motor was rigidly attached to the axle, whilst in others springs were introduced. The designing of a spring attachment for use at about 1000 revolutions per minute, and with an output of 750 H.P. per motor, was a difficult task. The problem was solved by connecting the motor to the wheel by an elastic coupling, and providing an elastic suspension for the motor, the springs being arranged so as to have increasing rigidity as the load increases. The motors are accordingly mounted on a hollow shaft, of which the surface speed in the bearings is nearly 15 m. per second. Experiments and observations have been made as to the friction both at this speed, and at others up to 25 and 30 m. per second, and under very great bearing pressures.

Starting Resistances for motors of 250 to 750 H.P. have already been used in practice, but the problem of arranging them in a confined space, for continuous use in current regulation in connection with a power of 4×750 H.P., has never before been contemplated. The relative advantages of liquid and metal resistances were considered in detail. The use of the former at first seemed out of the question, whilst the latter involved the employment of a large number of contacts, brushes, connecting cables, and resistance material, making them too heavy and cumbersome.

Four motors, each with three armature circuits, give a total of twelve phases, in each of which was inserted a resistance divided into twelve steps; but in spite of this sub-division, the regulation was found to be too jerky to be satisfactory. Ultimately a liquid starting device, that could be equally well used for large winding engines, was designed. The resistance material was a solution of soda, but the apparatus had nothing in common with the ordinary liquid starting resistance.

Taking into account the fact that a speed of 200 km. per hour was contemplated, it was arranged to provide, in addition to the Westinghouse air-brake, an *Electrical Brake*, which could be used either in connection with, or independently of, the source of current. The brake was so designed that it could be applied either gently or powerfully at will.

Other investigations were made besides those above referred to, and from the results obtained in the preliminary trials, there is every reason to hope that the motor car will meet all requirements, and enable the Association to deal with the questions relating to the running of the car on the track.

The paper contained full details, and many illustrations and plates.

The following members took part in the Discussion:—the Chairman, Sir William H. Preece, Herr E. Rathenau, Professor S. P. Thompson, Mr. A. Siemens, Professor Zipernowsky, Herr E. Kolben, Mr. Gisbert Kapp, Professor H. S. Carhart, and Professor C. A. Carus-Wilson.

The author replied by correspondence.

On the motion of the Chairman a vote of thanks was accorded to the author.

"DANGERS FROM TROLLEY WIRES AND THEIR PREVENTION."

Paper by Professor ANDREW JAMIESON.

Abstract.

THIS paper was treated under the following headings, and contained eight figures showing different kinds of trolley wire guards. Specimens and tests of the Glasgow Tramway trolley, guard, span, and tension wires, together with their various mechanical and electrical fittings; Post Office aerial lines and underground cables; as well as the National Telephone Coy.'s bare bronze wires and their overhead multiple wire cables, were shown and remarked upon by the author.

HEADINGS.

1. Recent accidents, and the necessity of keeping trolley wires free from contact with other overhead conductors.

2. Methods which have been adopted and proposed for protection against contacts with trolley wires.

3. Board of Trade and Post Office regulations.

4. Contacts between, and the breaking of, guard, span, and trolley wires.

5. Freeing, earthing, and other safety devices.

6. Aerial telephone and telegraph cables versus underground wires or cables.

Under the last heading the author stated, that there were now in Glasgow three authorities dealing with telephone wires, viz.:—

1. The Government Postal Engineering Department, who aimed at placing underground all their principal city wires which at present cross tramway routes.

2. The National Telephone Co., who had hitherto been prevented from opening the streets, and had until recently used bare, thin, bronze aerial wires, but who were now supplanting these (along the main routes which cross tramway lines) by multiple wire cables, each containing about 100 fine insulated wires. They employ two of these wires for each telephone circuit, upon the "closed circuit principle," in order to prevent inductive and earth interferences. These insulated cables were much safer than the bare wires.

3. The Glasgow Corporation, who, having full authority over their streets, had taken the precaution to place all their main telephone cables in underground cast-iron pipes.

He said: "There cannot be the slightest doubt, that the only sure and safe plan is, to place all non-tramway conductors, of whatever kind, underground. If this were done, then there would be no necessity for guard wires, thereby leaving the trolley wires free from extraneous contacts, and minimising the aforementioned dangers."

Mr. M. B. Field, M. Ernest Gérard, and Mr. G. R. Blackburn took part in the Discussion.

The author replied, and a vote of thanks was accorded to him.

"ELECTRICITY SUPPLY METERS OF THE ELECTROLYTIC TYPE."

Paper by J. R. Dick.

Abstract.

The author first directs attention to the attractiveness of meters of the electrolytic type on account of their inherent simplicity. In the case of electrolytic decomposition, where no secondary actions take place, the amount of electrolyte decomposed per second is directly proportionate to the strength of the current passing. Such a cell used as a meter will, therefore, register ampere hours perfectly. With motor meters it is necessary to find a special brake, the retarding effect of which corresponds to the driving torque, in order to get a straight line registration.

From the engineer's point of view the electrolytic meter has not had a permanent popularity. It has earned a bad reputation for various reasons, chiefly because it is "messy" and requires attention for the renewal of electrodes or electrolyte, and because of the great drop of pressure with the unshunted types. The simplest design of the latter character ever suggested was that of the water decomposing meter of S. D. Mott, described in the American "Electrical World" of March 4th, 1893, where the volume of water remaining after a current had passed through a known volume of water was used to measure the quantity of electricity which had passed through it. Attention was again redirected to this method of constructing an electricity meter in Mr. Gibbing's paper before the Inst. of Elect. Engrs. in 1898.

A short resume is then given of the faults which proved fatal to the older forms of electrolytic meters, such as Edison's, and an explanation is given, illustrated with many diagrams, showing how impossible it was to obtain accuracy at low loads when shunts were employed. There was always a certain amount of polarization, which made the ratio between the main and shunt currents not strictly constant. There are several methods of compensating for this E.M.F. of polarization, and thus obtaining a registration which is a linear function of the current. The best solution of the problem of a shunted electrolytic meter, however, is to find a form which gives no appreciable polarization. Such a meter can be devised where a volume of mercury deposited from a solution of mercurous nitrate measures the number of coulombs. Various forms of such a meter have been suggested from time to time—

e.g., those of M'Kenna in 1892, Munsberg in 1894, and Gordwitsch in 1898. In all of these forms the electrolyte is mercurous nitrate, and the anode is mercury, and the cathode either platinum, or carbon, or mercury. Advantage was taken of the fluidity of mercury to measure the volume of deposited metal instead of weighing it, as was necessary in the meters where copper or zinc was deposited.

There was one great difficulty, however, and that was to secure constancy in the resistance of the solution, and to prevent the formation of crystals on the anode. In all the forms mentioned above, the anode was placed below the cathode, and consequently the denser solution remained in contact with the anode, and finally, when it got too rich in the dissolved salt, it deposited crystals. There was no means of automatically mixing the solution so as to secure a uniformity of density. There was also the difficulty of resetting the instrument after the graduated receptacle became full of mercury. These defects have all been removed in the electrolytic meter, to which particular notice is directed in this paper. Here the anode is placed above the cathode, and is so arranged that its active surface is concentric with the latter. The mercury of the anode rises to such a height in its trough that the dense solution falls off the convex surface of the mercury by gravity, and the lighter solution rises from the cathode, and replaces the dense solution. This interchange of solution goes on continuously, and there is no need for agitation or stirring. The mercury anode surface is kept above the level of the cathode on the well-known "bird-fountain" principle. The design is such that the level and area of the surface always remain constant, and therefore the internal resistance of the electrolytic cell is also constant. The mercury deposited is first of all collected in a graduated tube forming one of the legs of the siphons. As soon as 100 units have been deposited and the tube is filled, the whole quantity shifts over into a larger tube. The volume of the siphon tube is equal to one division on the larger scale. The meter will thus register up to 1200 units without resetting.

The ratio between the main current and the shunt current passing through the electrolytic cell is 200 to 1. A high resistance in circuit with the electrolytic cell prevents errors due to change of temperature, and consequent diminution in the resistance of the latter. Copper wire is employed, the increased resistance of which acts as a correction to any change of the resistance of the cell itself with temperature.

The resetting of the meter to zero is accomplished by tilting the whole tube in a vertical plane, so that all the mercury which was deposited in the receptacle flows back into the anode chamber. The electrolytic cell is connected in the circuit across a shunting resistance of platinoid or other similar material, which has a drop in pressure not exceeding one volt at full load. There is no danger of a defect in the meter causing an interruption to the supply, as the main circuit is not completed through mercury. The electrolyte and the two electrodes are contained in a hermetically sealed glass tube. This is possible, as no gas is given off from the chemical action. There is, therefore, no necessity for renewing any of the parts of which the meter is composed. The mercury which is deposited from the cathode, on tilting the meter, is transferred to its original position in the anode chamber, and the whole cycle of operations can be repeated *ad infinitum.* There is no evaporation, there is no deterioration in the quality of the materials, no efflorescence due to atmospheric conditions, and the meter is entirely unaffected by changes in the barometic pressure; and, as the tests show, only to a very small extent by temperature.. There is practically no limit to its starting current, and the accuracy of its registration can be attained at all loads. Of four meters tested with a current of .05 of an ampere, two registered 100 per cent., one 95 per cent., of the whole quantity of electricity passed through them. The advantages of such a meter are obvious, and the simplicity and convenience of its design ought to remove the lingering objections which have hitherto applied to the general body of electrolytic meters. A conspicuous advantage is that there is no need to renew any of the parts, as, when once a meter is filled, it contains everything that is essential for its operation for an indefinite period as long as the glass tube remains intact. The ease of reading is a point not to be despised, as most people are familiar with the readings of a thermometer and barometer, and this is entirely similar. The cost of the meter, as in the case of most electrolytic meters, is comparatively small.

The author then gives the results of many tests which he has taken, showing the behaviour of the meter at light loads and at ordinary loads. Various results are given, showing how extremely minute is the value of e in the equation

$$E = Ri + \frac{\phi(i)}{i} + e$$

Tests of records at different temperatures are also given, and the paper concludes with some observations on the behaviour of the meter in practice.

On the motion of the Chairman a vote of thanks was accorded to the author.

"KELVIN'S ELECTRIC MEASURING INSTRUMENTS."

Paper by Professor MAGNUS MACLEAN.

Abstract.

LORD KELVIN has altogether 38 patents on electric instruments, and particulars of these are given in two appendices.

The instruments were classified under four heads:—

I. Electrometers.
II. Electromagnetic Instruments.
III. Electrodynamic Instruments.
IV. Recording Instruments.

I. Electrometers were divided into: —
(a) Symmetrical.
(b) Attracted Disc.

The Symmetrical include:—
(1) Quadrant Electrometers.
(2) Multicellular Electrometers.
(3) Vertical Electrostatic Voltmeters.

The Attracted Disc include:—
(1) Absolute Electrometers.
(2) Long Range Electrometers.
(3) Portable Electrometers.
(4) Electrostatic Balances.

No description of these well-known instruments was given, but a standard air Leyden condenser was fully described, as, in conjunction with a suitable electrometer, it affords a convenient means of quickly measuring small electrostatic capacities, such as those of short lengths of cables.

II. Electromagnetic Instruments include:—
(1) Reflecting, differential, and ballistic Galvanometers.
(2) Graded Galvanometers.
(3) Suspended-coil Amperemeters and Voltmeters in six different types:—(a) Edgewise pattern, (b) Round pattern, (c) Thistle pattern, with or without illuminated dial, (d) Portable pattern in aluminium case, (e) Portable paralleling pattern, and (f) Reflecting mirror pattern.
(4) Ampere Gauges.

The ampere gauges have had two very important improvements introduced of late years. The first improvement relates to the coil, and the object is to obtain a coil which will give a more uniform field than is attained by ordinary methods. The second improvement relates to the method of suspending the soft iron plunger which is now suspended from a sector. These two improvements were described.

III. The Electrodynamic Instruments include:—
(1) Ampere balances.
(2) Watt balances.
(3) Engineroom Wattmeters.
(4) Three-phase Wattmeters.

Particulars and diagrams of the coils of the engine-room and three-phase Wattmeters were given.

IV. The Recording Instruments include:—
(1) Amperemeters of the ampere gauge sector pattern.
(2) Voltmeters of the ampere gauge sector pattern.
(3) A combination of IV., 1 and 2, called a Feeder Log.
(4) Astatic Voltmeters on the principle of Wattmeter III., 3.
(5) Astatic Wattmeters like IV., 4, except that the fixed coils are of copper ribbon, and carry the main current, while the movable coils with electric lamps in series with them take the shunt current.

The instruments were also classified as follows:—

I. Standard Instruments:—
(1) Ampere Balances.
(2) Watt Balances.
(3) Multicellular Electrostatic Voltmeters.
(4) Vertical Electrostatic Voltmeters.
(5) Quadrant Electrometers.
(6) Absolute Electrometers.

II. Portable Instruments:—
(1) Horizontal Multicellular Voltmeters.
(2) Portable Suspended Coil Amperemeters and Voltmeters.
(3) Testing Set for measuring insulation resistance.
(4) Cell Tester.
(5) Rail Tester.
(6) Paralleling Voltmeters.
(7) Graded Galvanometers for currents and potentials.
(8) Portable Electrometers.

III. Central Station Instruments:—
(1) All the Electrostatic Voltmeters.

(2) The Suspended Coil Voltmeters and Amperemeters.
(3) The Ampere Gauge Recording Voltmeters and Amperemeters, including the Feeder Log.
(4) Earth Current Recorder.
(5) Astatic Recording Voltmeters for alternating currents.
(6) Recording Wattmeters.
(7) All the types of Ampere Gauges.
(8) Engine-room Wattmeters.
(9) Three-phase Wattmeters.
(10) Rail Tester.

The paper was illustrated by twenty-five figures.

Mr. W. A. Chamen took part in the Discussion, and on the motion of the Chairman a vote of thanks was accorded to Professor Maclean.

(Appendices, see pp. 329-330.)

PATENTS RELATING TO IMPROVEMENTS IN APPARATUS FOR GENERATING, REGULATING, MEASURING, RECORDING, AND INTEGRATING ELECTRIC CURRENTS.

Number of Patent.	Date of Provisional Specification and of Complete Specification.	TITLE OF PATENT.	Number of Pages.	Number of Sheets.	No. of Figs. or Diagrams.
3032	July 9, 1881 Jan. 9, 1882	Improvements in regulating electric currents, and in the apparatus or means employed therein, - -	11	3	9
5668	Dec. 26, 1881 June 28, 1882	Improvements in dynamo-electric machinery, and apparatus connected therewith, - -	18	13	70 lapse
2028	April 21, 1883 Oct. 20, 1883	Improvements in apparatus and processes for generating, regulating and measuring electric currents	28	25	48
4617	Sept. 28, 1883 Mar. 27, 1884	Apparatus for generating, regulating, measuring, recording, and integrating electric currents, -	41	18	36
4655	Mar. 10, 1884 Oct. 8, 1884	New or improved suspensions for electrical incandescent lamps, -	4	1	2
5355	Mar. 22, 1884 Nov. 10, 1884	Improvements in dynamo-electric machinery, - - - - -	3	1	5
6410	Mar. 10, 1884 Oct. 28, 1884	Improvements in breaking electric contact to prevent over-heating by imperfect contact, - -	3	2	6
10530	July 24, 1884 April 25, 1885	Safety fuses for electric circuits, -	7	1	13
11106	Aug. 9, 1884 May 7, 1885	Improvements in apparatus for measuring electric currents, -	10	6	7
9016	July 10, 1886 April 9, 1887	Improved apparatus for measuring the efficiency of an electric circuit (Amended Oct. 4, 1897), -	13	28	40
18035	Dec. 11, 1888 Sept. 7, 1889	Electrostatic apparatus for measuring potentials, -	4	3	7
18035a	Dec. 11, 1888 Sept. 7, 1889	An improved ampere gauge and connections, - -	3	3	6
18035b	Dec. 11, 1888 Sept. 7, 1889	Improved apparatus for continuously measuring potentials or currents, - - - -	3	2	3
15769	Oct. 8, 1889 July 7, 1890	Apparatus for measuring and recording electric currents (allowed to lapse), - - -	4	3	4
1004	Jan. 20, 1891 Oct. 20, 1891	An improved indicator for electric potentials, - - -	2	1	3
18436	Oct. 27, 1891 July 22, 1892	Improved apparatus for measuring and recording electric currents, -	5	3	6
10230	May 30, 1892 July 2, 1892	An improved electric condenser, -	2	2	2
2198	Feb. 1, 1893 Nov. 1, 1893	Improvements in balances, -	2	1	5

Number of Patent.	Date of Provisional Specification and of Complete Specification.	TITLE OF PATENT.	Number of Pages.	Number of Sheets.	No. of Figs. or Diagrams.
2199	Feb. 1, 1893 Feb. 1, 1893	An instrument for measuring electric currents, - -	3	1	4
5733	Mar. 17, 1893 Dec. 16, 1893	Improved arrangement for reading the deflections of electric instruments, -	2	1	2
24471	Dec. 20, 1893 Oct. 20, 1894	Improvements in electric supply meters, - - - -	3	1	2
24979	Dec. 29, 1893 Dec. 29, 1894	Improvements in instruments for measuring and recording electric pressures and currents, - -	1	3	5
15034	Aug. 7, 1894	Improvements in instruments for measuring electric currents, -	—	—	—
2261	Nov. 27, 1895 Sept. 28, 1896	Improvements in apparatus for indicating and recording electric supply, - - - -	5	1	2
18438	Aug. 9, 1897 May 9, 1898	Improved coil for electric instruments, - - - -	3	1	5
21716	Oct. 15, 1898 July 14, 1899	Improvements in electric measuring instruments, - - - -	2	1	1
3937	Mar. 1, 1900 Dec. 1, 1900	Apparatus for indicating and recording electric pressure and current,	3	1	4

PATENTS RELATING TO IMPROVEMENTS IN TELEGRAPHIC APPARATUS.

329	Feb. 20, 1858 Aug. 19, 1858	Improvements in testing and working electric telegraphs, - -	36	1	9
329	May 19, 1871	Disclaimer, - - -	19	—	—
2047	Aug. 25, 1860 Feb. 25, 1861	Improvements in the means of telegraphic communication, -	37	4	27
1784	July 6, 1865 Jan. 6, 1866	Improvements in electric telegraphs, - - -	14	1	9
2147	July 23, 1867 Jan. 23, 1868	Improvements in receiving or recording instruments for electric telegraphs, - -	10	1	7
3069	Nov. 23, 1870 Not allowed.	Improvements in electric telegraph transmitting, receiving, and recording instruments, and in clocks, - - - -	33	—	—
252	Jan. 31, 1871 July 31, 1871	Improvements in transmitting, receiving, and recording instruments for electric telegraphs, -	24	7	37
810	Mar. 25, 1871 Void.	Improvements in clocks and apparatus for giving uniform motion	4	—	—
2086	June 12, 1873 Dec. 12, 1873	Improvements in telegraphic apparatus, - - -	14	4	11
1095	Mar. 13, 1876 Sept. 13, 1876	Improvements in telegraphic apparatus, - - -	16	4	21
24868	Dec. 28, 1895 Sept. 28, 1896	Improvements in recording instruments for telegraphic and other purposes, - - - - -	4	2	6

THURSDAY, 5th SEPTEMBER, 1901.

W. LANGDON, Chairman, in the Chair.

The Chairman gave the substance of a communication he had received from Dr. Glazebrook regarding the National Physical Laboratory and the work which was to be done there.

"THE RELATIVE ADVANTAGES OF THREE, TWO, AND SINGLE PHASE SYSTEMS FOR FEEDING LOW-TENSION NETWORKS."

Paper by M. B. FIELD.

Abstract.

A TRACTION system is first considered where the distribution of power is effected by means of continuous current at 500 volts, from various sub-stations, these being fed from a single distant generating station with high tension alternating currents. It is assumed that the choice of frequency is open.

The choice of converter lies between:—

(1) Rotary converters with transformers.
(2) Synchronous motor generators without transformers.
(3) Non-synchronous motor generators without transformers.

Tables are given showing that—(1) of rotary converters, the six-phase rotary used on a three-phase system is the best, owing to the greater load per unit weight it will carry; (2) the rotary converter is lighter, more efficient, cheaper, and equally as simple and practicable a converter as a motor generator, provided the frequency be kept low; (3) the multi-phase converter of whatever type is preferable to the single-phase converter. The single-phase rotary is not a practicable converter, and is not considered.

CABLES.—It is pointed out that the three-phase system should theoretically give the minimum weight of copper in the transmission line per kw. transmitted, with given percentage loss and strain upon the insulation of generators, cables, etc. A specific case is considered, a three-phase transmission one mile long at 6500 volts per phase, transmitting 1000 kw. through three-core cables, being taken as a working basis of comparison.

The alternatives are for single-phase—

(1) One concentric cable.
(2) Two independent single-core cables.
(3) One two-core cable.

For two-phase—

(1) Two concentric cables.
(2) Four single-core cables.
(3) Two two-core cables.
(4) One four-core cable.

In comparing the various systems, either the strain on the insulation of the generators, transformers, etc., may be kept the same in each case, or the strain in the insulation of the cables may be kept the same. These are two entirely different conditions, which do not necessarily hold simultaneously. Conditions are also varied when the neutral point of the generating system is earthed, and when it is not earthed. Various cases are considered and discussed, the result arrived at being in favour of three-core cables and a three-phase supply.

Board of Trade regulations may have an important bearing on the choice of the system. For example, if an earthed shield be required, and for this reason two concentric cables be used for a two-phase system, the outers forming a common main may have each a smaller cross section than the corresponding inner conductor. This will mean less copper for the two-phase system than for the corresponding single-phase system. If no earth shield be provided, and concentric cables be avoided, and in their place two-core cables be adopted, the weight of copper is the same for the two systems. If, on the other hand, three-core cables be used for a three-wire two-phase system, all cores being insulated from earth, a greater weight of copper is required for the two-phase than for the single-phase system, if they are both placed on the same basis as regards strain on insulation.

GENERATORS.—Three-phase generators are cheaper and lighter than single-phase generators, and the synchronising effects are greater.

When it is a question of mixed lighting and power, and a higher frequency is adopted, the advantages of the three-phase system are not so predominating. Single-phase motors, though not so efficient, and having a lower power factor than three-phase motors, are nevertheless very serviceable motors. Frankfort is instanced as a case where a large amount of motor power is distributed from lighting circuits successfully. In well laid out three-phase schemes lights may be connected to motor circuits, and a mixed system may thus be adopted with very good results.

If the transmission from the generating station to the transforming centres be a long one, economy is obtained by adopting a three-phase transmission. There is, however, no economy in a three-phase distribution where lamps are connected between each pole and the neutral point of the system, as against a single-phase distribution laid out on the three-wire system.

Hence the adoption of two-phase systems in cases where the transmission losses are not great, and where both motors and lamps are connected. The advantage will be emphasised if the system be hampered by Board of Trade regulations, as stated above.

A three-phase combined system adopted in America has met with a certain amount of favour where the voltage of one phase alone is kept constant, all incandescent lamps being connected across this phase. In such a case the other phases are loaded in any way in which it is not essential to keep the voltage absolutely constant. In this case no attempt is made to keep the phases balanced. Three-phase motors and transformers are connected across all three phases. The effect of this is to tend to equilibrate the load on the three phases, since a motor takes most power from the phase of which the voltage is highest. A good three-phase generator may be used as a single-phase generator up to about 75 per cent. of its rated output. It is pointed out that an unbalanced load of this nature goes far to counteract the special economy of the three-phase system, in which case a two-phase system would probably be equally advantageous.

The following members took part in the Discussion:—the Chairman, Herr E. Kolben, Professor H. S. Carhart, Mr. W. B. Esson, Professor Silvanus Thompson, Mr. W. G. Rhodes, Herr O. T. Blathy, Mr. Gerald Stoney, Mr. W. Geipel, Mr. F. Broadbent.

The author replied, and a vote of thanks was accorded to him.

"MODERN COMMUTATING DYNAMO MACHINERY, WITH SPECIAL REFERENCE TO THE COMMUTATING LIMITS."

Paper by H. M. Hobart.

Abstract.

In the design of the continuous current dynamo, in spite of the lapse of many years since the introduction of such machinery, there is not that progress observable which has characterised electrical engineering in general. There is certainly still very great opportunity for improvement, and much may be done without any radical innovations, merely by making more general use of the technical knowledge of the subject at present at our disposal. One persistent error has been the perhaps natural assumption that the kilowatts output should be given predominating consideration in laying down the lines of the design, and that the required volt- and amperage are of altogether minor importance. This has led to the frequent use of very inappropriate designs, particularly with relation to the commutator, the armature winding, and the number of poles and general construction of the magnetic circuit. Machines of different voltages, but for the same kilwatts output, have, however, one set of features in common—namely, all those features relating to the amount of mechanical power to be transformed into electrical, or vice versa; in other words, the *mechanical* design in general. The paper goes on to describe a group of machines designed with due regard not only to these features of mechanical similarity, but also to the points where the designs should diverge in order to suitably comply with the requirements of the different voltage and current ratings. In these machines, which are described in considerable detail, the base, stands, bearings, and shaft are the same for all voltages, but while in the low voltage design the electro-magnetic part of the machine is extremely narrow and the commutator wide, the high voltage machine has precisely the opposite characteristics. Since, however, the diameter of commutator, armature, field bore, and magnetic yoke are the same for all voltages, it is quite practicable to use to a great extent the same drawings and patterns for all voltages, the patterns being extended or not according as castings for machines of the one or the other voltage are required. It is shown how naturally all this works out, and the opinion is put forth that by

the use of these principles the best results for a given outlay may be obtained. For the group of machines described, which range from 80 kilowatts at 580 *r.p.m.* to 150 kilowatts at 425 *r.p.m.*, the cost for "net effective material" was quite uniformly 16.3 shillings per kilowatt for all voltages. The guarantee to which they were designed is given as follows:—25 per cent. overload for one half hour without harmful sparking or heating. Thermometrically measured temperature increase of warmest part not to exceed 50 deg. Cent. above surrounding atmosphere during continuous operation at rated load. No harmful sparking or heating with momentary overloads of 50 per cent. Fixed brush position for all these conditions. Insulation of entire machine, from copper circuits to iron, to withstand for one minute at 20 deg. Cent. the application of the following R.M.S. voltages:—

Rated Voltage.	Test Voltage.
115	2500
230	3000
550	3500

Incidentally the assertion is made that low reactance voltage greatly outweighs in importance low armature strength so far as relates to excellence in commutation, and high commutator peripheral speeds are advocated on account of the very great improvement in commutating constants thereby rendered practicable. Careful attention to all these different considerations still permits of a fair degree of interchangeability and uniformity in the designs for different voltages of the same kilowatts output.

The paper treats in considerable detail of the author's (*) method of estimating the reactance voltage. The following principles underlie this method:—Experiments on various arrangements of armature slots of a wide range of shapes and sizes, with variously proportioned coils arranged in many ways with respect to these slots, have shown that the number of *c.g.s.* lines of magnetic flux

* This method of estimating the reactance voltage is based upon substantially the same principles as the method published two years ago by Mr. H. F. Parshall and the present writer. The novelty in the method, as then described by them, consisted chiefly in starting from the basis of representative values for the inductance, as expressed in terms of the lines set up per ampere turn per unit of length of laminations, and it led to substantially the same results as one obtains by the method in its present form. As now set forth, it allocates the components of the inductance in the "free" and "embedded" lengths respectively, giving guiding values for estimating these components, and supporting them by fairly thorough tests and by experience gained in applying the method to a great variety of machines, so that now, it is believed, the method may be employed still more effectively.

set up per ampere-turn of these coils may, as an average, be taken at—

4.0 lines per centimetre of "embedded" length.
0.8 „ „ "free" „

The tests made showed a very much smaller range of variation in these values for different proportions than has generally been considered to be the case; hence, while in abnormal cases modified values should be taken, one may, nevertheless, in the great majority of designs, make an amply sufficient approximation to the reactance voltage by the use of these average values. In the course of the description of this method, the following rather interesting conclusion is pointed out:—

The inductance of a coil laid upon the surface of the armature —*i.e.*, on the lines formerly so frequently employed, and sometimes nowadays termed "smooth core" construction—is, with customary proportions, rarely much less than one-third, and often one-half or more as great as in the case of the same coil laid in slots.

This conclusion follows from the experimental result that with ordinary open slots, with parallel sides, of the proportions generally found in modern continuous-current generators, the inductance per centimetre of "embedded" length is generally only some 4 to 6 times greater than the inductance per centimetre of "free" length, and with the dimensions of face conductors and end connections nowadays generally used, the inductance of the "free" length is a very considerable percentage, say 25 to 40 per cent., of the total inductance of a coil.

After illustrating these methods and principles by data of a number of designs of machines of all sizes, the paper takes up the consideration of the case of large high-speed commutating machines, and it is stated that, by the employment of high armature reaction (as expressed in armature ampere-turns per pole piece), and high commutator peripheral speeds, even 600 volt machines of large capacity may be designed with excellent commutating properties for high speeds.

The paper closes with mention of the large number of ratings required to meet all the present commercial requirements for a line of small motors, and expresses the opinion that it is false economy not to admit at the outset the magnitude of the undertaking of manufacturing such a complete line.

The Discussion on this paper was combined with that on the paper by Mr. H. A. Mavor (see p. 340).

The author replied at the meeting and by correspondence, and a vote of thanks was accorded to him.

"DESIGN OF CONTINUOUS-CURRENT DYNAMOS."

Paper by HENRY A. MAVOR.

Abstract.

THE present methods of designing dynamos and recording results do not readily lend themselves to comparison of machines of different outputs. It would, therefore, be of advantage if a suitable unit of comparison could be devised, and it is suggested that a consideration of the continuous-current dynamo, leaving out of account all the non-essential elements of design and construction, and concentrating attention upon the vital portion of the machine which alone is concerned in the direct generation of energy, would lead to a suitable basis of comparison.

It is therefore proposed to consider as a whole the region occupied by the armature conductors in the magnetic field. This region may be named the "active belt" of the armature. It is bounded by the peripheral surface of the armature, the surface of the core at the bottom of the slots and the ends of the core. An examination of the machine in the terms of the energy generated in this "active belt" leads to the interesting result that machines of very widely varying size, output, and speed, give a remarkably constant value in watts generated per cubic centimetre at unit velocity in unit field. This constant may be expressed in symbols thus:—

$$(1) \qquad K = \frac{W}{\pi dls \times \pi dn \times F}.$$

The value of the constant K must be a compromise between economy in first cost and efficiency of radiation of lost watts. The maximum value gives zero electrical efficiency; the maximum possible output of the machine is at half this value.

A reduction of value of the constant leads to increased quantity of material, increased cost of construction, and increased electrical efficiency. A consideration of the dynamo from this point of view suggests increase in the depth of the "active belt," reduction in the watts generated per cubic centimetre, and reduction in the depth of the core so as to minimise hysteresis and eddy current losses in the core, with consequent increase in diameter and multiplication of the number of poles. A comparison between the results obtained by different designers of the proper value of this constant should

be of immediate interest. It will be noted that this consideration includes the radiation of all lost energy from the surface of the armature, the value being the total watts generated by the machine.

The total electromotive force of the machine in volts is given by

$$(2) \qquad E = \frac{2\pi d l F G m n}{p \times 10^8}$$

The reactance voltage of any machine considered on the lines of Messrs. Parshall & Hobart's book on "Electric Generators" may be ascertained by a very simple calculation. Assuming a sine wave form for the fluctuations in the current under commutation, the value of the reactance voltage is given by the formula:—

$$(3)\ r = \frac{2\pi \frac{G}{b} n f l b m^2 C}{p \times 10^8};$$

and from 2 and 3

$$(4) \qquad r = \frac{ECfm}{dF}.$$

The value of the field f due to the current under commutation is probably not so constant as indicated in the work above referred to, but any desired correction may be made on this factor by introducing the relation between the depth and width of the slot or any elements which the designer may consider it necessary to introduce. The value of F, the average field, per unit surface of the core being practically constant, the reactance voltage of any machine can be ascertained practically by inspection. This formula (4) indicates that the reactance voltage is not subject to much modification for any given output.

The average *emf* generated in m turns of the winding

$$(5) \qquad e = \frac{2\, m l F\, \pi d\, n}{10^8}.$$

In lap wound armatures e equals difference of potential between adjacent sections of the commutator.

In wave wound armatures the difference of potential between adjacent sections of the commutator equals

$$e \times \frac{\text{Poles}}{2}$$

From these formulæ are derived—

$$(6) \quad \frac{GmC}{p} = \frac{K \times \pi ds \times 10^8}{2} = \text{Ampere turns in the armature.}$$

(From 1 and 2.)

(7) $\frac{e}{r} = \frac{dFp}{fGmC}$. (From 3 and 5.)

(8) $\frac{e}{r} = \frac{2F}{K\pi fs10^8}$. (From 1, 4, and 5.)

(9) $\frac{e}{r} = \frac{2\pi F^2}{60f10^8} \times \frac{d^2lR}{W}$. (From 1 and 8.)

Curves are plotted of 7, 8, and 9, showing the relation of ampere turns on armature, slot depth and armature dimensions, to the reactance voltage and *e.m.f.* between commutator segments.

Turning now to the consideration of cost, it is found that in the case of many groups of machines there is no regular ratio between the cost and the output. There ought to be such a regular relation, and the following method is suggested for obtaining this result:—

Plotting watts per revolution as abscissae and costs as ordinates, the position of each machine is marked, and the points representing cost and output for each carcase of a given diameter with varying length are joined by a straight line which is produced to the origin. The point where this line cuts the zero ordinate gives the limit of cost to which this carcase approaches as the core length is reduced to zero, and may be called the base cost of any given carcase; the slope of the line drawn through the costs of the machine at different lengths show the cost per inch length of "active belt" on that carcase. Increase of diameter increases the base cost and reduces the slope of the line passing through the costs of the actual machines, so that, starting from the smallest diameter and passing to the largest, will give a succession of straight lines, each touching its next lower neighbour at one point, and producing a curve made up of segments of the lines representing each machine, each segment showing the economical range of length for the machine which it represents.

Symbols used in this Paper.

A = Length of air space.

b = The maximum number of sections of commutator covered by the brush.

C = Total armature current in amperes.

d = Diameter of core measured to the middle of the active belt in centimetres.

e = Average *e.m.f.* generated in m turns of the winding in volts.

E = Total *e.m.f.* generated by armature in volts.

f = Induction Field in *c.g.s.* lines per centimetre length of slot, due to one complete turn.

F = Average Flux taken over the whole surface of the armature, in *c.g.s.* lines per square centimetre.
G = Number of sections in the commutator.
K = Watts generated per cubic centimetre of active belt at unit velocity in unit field, called energy factor.
l = Nett length of armature core in centimetres.
m = Armature turns per commutator section.
n = Revolutions of armature per second.
P = Number of poles in magnets.
p = Number of paths through armature.
r = Reactance voltage.
s = Depth of slot in centimetres.
R = $60n$ = revolutions per minute.
W = EC = Total watts generated by active belt.

The Discussion on this paper was combined with that on Mr. Hobart's paper, and was taken part in by the following members:—Mr. H. A. Mavor, Mr. Gisbert Kapp, Professor Silvanus P. Thompson, Mr. W. A. Chamen, Mr. W. B. Sayers, Col. R. E. Crompton, and Mr. W. B. Esson (communicated).

The authors replied, and a vote of thanks was accorded to them.

The following votes, proposed by the President, were passed:—(first) that the thanks of the members of the Section be given to Dr. Caird and the Committee of the Congress, and to the General Secretary, for the admirable arrangements made both for the comfort and convenience of the members, and (second) that the best thanks of the Institution of Electrical Engineers be given to the University of Glasgow and to Professor Gray for the use of the Natural Philosophy Theatre for the meeting.

A vote of thanks was also accorded to the President on the motion of Professor Jamieson.

This closed the business of the Section.

List of Societies and Institutions in Great Britain and Ireland which took part in the Congress.

The Aberdeen Mechanical Society.
The Cleveland Institution of Engineers.
The Glasgow University Engineering Society.
The Glasgow and West of Scotland Technical College Scientific Society.
The Hull and District Institute of Engineers and Naval Architects.
The Incorporated Association of Municipal and County Engineers.
The Incorporated Gas Institute.
The Incorporated Institution of Gas Engineers.
The Incorporated Municipal Electrical Association.
The Institution of Civil Engineers.
The Institution of Civil Engineers of Ireland.
The Institution of Electrical Engineers.
The Institution of Engineers and Shipbuilders in Scotland.
The Institution of Junior Engineers.
The Institute of Marine Engineers.
The Institution of Mechanical Engineers.
The Institution of Mining Engineers.
The Institution of Naval Architects.
The Iron and Steel Institute.
The Liverpool Engineering Society.
The Manchester Association of Engineers.
The Mining Institute of Scotland.
The North British Association of Gas Managers.
The North-East Coast Institution of Engineers and Shipbuilders.
The Royal Engineers Institute.
The Society of Engineers.
The South Wales Institute of Engineers.
The West of Scotland Iron and Steel Institute.

List of Foreign and Colonial Delegates and Honorary Members.

AUSTRALIA.

Australasian Institute of Mining Engineers, Melbourne.

James Stirling, 15 Victoria Street, Westminster, London, S.W.

Victorian Institute of Engineers.

George Higgins, 60 Martel Street, Melbourne, Victoria, Australia.

R. W. Richards, City Surveyor, Sydney, N.S.W.
J. M. Smail, Chief Engineer to the Metropolitan Board of Works, Sydney, N.S.W.

AUSTRIA.

Ministry for Education and Public Worship.

Professor Karl Hochenegg, Technical High School, Vienna.

Ministry for Railways.

Karl Goelsdorf.

Oesterreichischer Ingenieur-und Architekten Verein Vienna.

Professor Fritz Edler von Emperger, Technical High School, Vienna.
Oskar Guttmann, 12 Mark Lane, London, E.C.
C. de Kierzkowski-Stewart, 17 Victoria Street, Westminster, London, S.W.
F. Krauss, Seilerstrasse 11, Vienna, I/1.
J. Spacil, 1 Zollamtstrasse, Vienna, III/2.

Karl Jenny, Chief of Locomotive Shops, Austrian Southern Railway, Innsbrück.
Emil Kolben, Vysocan-Prag, Austria.
M. Pichler, Chief of the Construction and Traffic Department, Austrian State Railways, Vienna.
M. G. Rank, Fuhrmannsgasse, Vienna, VIII/2.
A. Smreck, Belcredi Strasse, 831, Prag, Austria.

BELGIUM.

Ministère des Finances et des Travaux Publics.

J. Troost, Inspecteur Général des Ponts et Chaussées, Bruxelles.
J. Pierrot, Directeur des Ponts et Chaussées, Bruxelles.
L. Van Gansberghe, Directeur des Ponts et Chaussées, Ostend.
H. Vander Vin, Ingénieur Principal des Ponts et Chaussées, Bruxelles.

Ministère des Chemins de Fer, Postes et Telegraphes.

M. Gérard, Ingénieur en Chef, f. f. d'Inspecteur Général, Bruxelles.
M. Van Bogaert, Ingénieur Principal, Bruxelles.

Ministère de l'Industrie et du Travail, Bruxelles.

J. F. Demaret, Ingénieur Principal, Corps des Mines, Bruxelles.
M. Libert, Ingénieur en Chef, Corps des Mines, Bruxelles.
V. Watteyne, Ingénieur en Chef, Corps des Mines, Bruxelles.

Société Géologique de Belgique, Liége.

Professor A. Habets, 4 Rue Paul Devaux, Liége.

Société Belge de Géologie, de Paléontologie et d'Hydrologie, Bruxelles.

Ernest Van den Broek, Sécretaire-Général, 39 Place de l'Industrie, Bruxelles.

Association des Ingénieurs Sortis de l'Ecole de Liége.

Adolphe Greiner, General Manager, Société Anonyme John Cockerill, Seraing, Belgium.

Association des Gaziers Belges, Liége.

M. Boscheron, 13 Rue Simon, Liége.
M. Busine, Boulevard Baudoire-le-Batisser, Mons.
M. Escoyez, Tertre-lez-Baudour, Belgium.
M. Salomons, 133 Chaussée d'Ixelles, Bruxelles.
M. Tricot, Directeur de l'Usine à Gaz de Mons, Mons.
M. Trifet, Administrateur, Délegué de la Société des Usines à Gaz Réunies.
M. Van Heede, Usine à Gaz de Koekelberg-Bruxelles, Belgium.
M. Verstraeten, 26 Rue Marie de Bourgogne, Bruxelles.

Société des Ingénieurs Sortis de l'Ecole Provinciale d'Industrie et des Mines du Hainaut.

Professor Henry Van Laer, 83 Rue de Berckmons, Bruxelles.

E. Bouillon, Chef du Service des Voies et Travaux, Société Nationale des Chemins de Fer, Vicinaux, Bruxelles.
Emile Harze, 213 Rue de la Chaussée, Bruxelles.
A. Heyland, 32 Rue du Marteau, Bruxelles.
John Kraft de la Saulx, Seraing, Belgium.
A. Lecointe, 38 Rue Albert, Ostende.
L. Petit, Ingénieur-en-Chef de la Traction et du Matérial, Société Nationale des Chemins de Fer, Vicinaux, Bruxelles.
E. Putzeys, Ingénieur-en-Chef, Directeur de la Ville, Bruxelles.
E. de Rudder, Ingénieur-en-Chef des Voies et Travaux, Chemins de Fer de l'Etat, Bruxelles.
Jules Semol, 148, Rue Gollait Bruxelles.
Gustave Wolters, Université de Gand, Gand.

BRITISH CENTRAL AFRICA.

Percy Cullen, Fort Johnston, British Central Africa.

CANADA.

Canadian Society of Civil Engineers, Montreal.

G. C. Cunningham, Tramway Office, Birmingham, England.
James Ross, 877 Dorchester Street, Montreal.

CAPE COLONY.

R. O. Wynne-Roberts, City Engineer, Cape Town.

CEYLON.

Francis A. Cooper, Director of Public Works, Colombo.
Robert Skelton, Municipal Engineer, Colombo.

CHILI.

Alejandro Bertrand, 41 Victoria Road, Kensington, London, W.

CHINA.

C. Mayne (Shanghai), c/o Mrs Bartlett, Church Street, Steyning Sussex.

DENMARK.

Danish Government.

J. O. V. Irminger, Gas Works, Copenhagen, Denmark.
C. Hummel, Engineer of Danish State Maritime Works, Copenhagen.
H. A. R. Elben, Engineer-in-Chief, Way and Works Department, Danish State Railways, Copenhagen.
Captain A. Rasmussen, R.D.N., Royal Dockyard, Copenhagen.
Professor C. Ph. Teller, Hellerup.

Dansk Ingeniör Förening, Copenhagen.

C. R. Oellgaard, 32 Oestersögade, Copenhagen K.
G. A. Hagemann, 51 Bredgade, Copenhagen K.

Christian Otterstrom, Helenevig 5, Copenhagen.
Captain J. C. Tuxen, R.D.N., Royal Dockyard, Copenhagen.

FINLAND.

Tekniska Föreningen i Finland, Helsingfors.

Baron K. E. Palmen, Forssa, Finland.

FRANCE.

Ministère de la Marine, Paris.

M. Berrier-Fontaine, Directeur du Génie Maritime, Paris.
M. Bertin, Directeur du Génie Maritime, 8 Rue Garancière, Paris.
M. Pollard, Directeur de l'Ecole d'Application du Génie Maritime, Paris.
M. de Courville, Attaché à la Section Technique des Constructions Navales, Paris.
M. de Miniac, Directeur des Travaux Hydrauliques du Port de Brest, Brest, France.
M. Callou, Ingénieur en Chef de la Marine, Portrieux (côte du Nord), France.

Ministère des Travaux Publics.

Baron Quinette de Rochemont, Inspecteur-Général des Ponts et Chaussées, 43 Avenue du Trocadero, Paris.
M. Ribière, Ingénieur en Chef des Ponts et Chaussées, Paris.

Société des Ingénieurs Civils de France.

E. Cornuault, 10 Rue Cambacérès, Paris.
M. Jannettaz, 78 Rue Claude-Bernard, Paris.
M. Regnard, 53 Rue Bayen, Paris.

Société de l'Industrie Minerale, Saint Etienne.

M. Le Neve Foster, Llandudno, North Wales, England.
M. Verney, Ingénieur Civil des Mines, St. Etienne.

Société Géologique de France.

Professor J. Bergeron, 157 Boulevard Haussmann, Paris.

Association Technique Maritime.

A. Normand, 67 Rue du Perrey, Havre.
E. Bertin, 8 Rue Garancière, Paris.

Société d'Encouragement pour l'Industrie Nationale.

M. Rozé, 62 Rue du Cardinal, Paris.

Société Technique de l'Industrie du Gaz en France.

E. Cornuault, 10 Rue Cambacérès, Paris.
Fernand Bruyère, 65 Rue de Provence, Paris.

C. H. Baudry, Rue Blanche 19, Paris.
Georges Bechmann, 9 Place de l'Hotel-de-Ville, Paris.
Voisin Bey, Rue Scribe 3, Paris.
M. Briere, Ingénieur-en-Chef de la Voie et des Travaux, Chemin de Fer d'Orleans, Paris.
C. J. Canet, 42 Rue d'Anjou, Paris.
M. Chevalier, Ingénieur-en-Chef des Travaux, Compagnie des Chemins de Fer Departmentaux, Paris.
M. Comble, Ingénieur-en-Chef de la Traction Compagnie des Chemins de Fer Departmentaux, Paris.
V. Daymard, 6 Rue Auber, Paris.
L. de Bussy, Rue de Jouy 7, Paris.
Haton de la Goupillière, Boulevard St. Michel 60, Paris.
F. B. de Mas, Avenue Jules Janin 8, Paris.
M. Denis, Ingénieur-en-Chef de la Voie, Chemin de Fer Paris, Lyon et de la Mediterranée, Paris.
A. de Montgolfier, St. Chamond, Loire, France.
L. Févre, Ingénieur au Corps des Mines, Arras, France.
X. Gosselin, Rue de St. Quentin 12, Paris.
M. Goupil, Ingénieur-en-Chef de la Voie, Chemin de Fer de l'Ouest, Paris.
Adolphe Guerard, Rue Picot 8, Paris.
P. Holts, Rue de Milan 24, Paris.
F. Hospitalier, Rue de Chantilly 12, Paris.
Maurice Levy, Avenue du Trocadéro 15, Paris.

C. Linder, Rue de Rennes 44, Paris.
Prof. E. Mascart, Rue de l'Université 176, Paris.
P. Mengin-Lecreulx, Rue de Rennes 148, Paris.
L. Ribourt, Rue Caumartin 64, Paris.
E. Schneider, Rue d'Anjou 42, Paris.
M. Vainet, Ingénieur-en-Chef des Travaux, Chemin de Fer du Nord, Paris.

GERMANY.

Schiffbautechnische Gesellschaft.

H. Rudloff, Leipziger Platz 13, Berlin W.
H. Zimmermann, Schiffswerft Vulcan, Bredow b/ Stettin.

Verein Deutscher Ingenieure.

O. von Miller, Ferdinand Miller Platz 3, München.
Professor M. Schröter, München.
R. Diesel, Maria Theresia Str. 32, München.
O. Lasche, c/o Verein Deutscher-Ingenieure, Berlin.

Deutscher Verein von Gas und Wasserfachmœnnern.

Dr. Leybold, Gas Works, Hamburg.

Ernst Borsig, Heydtstrasse 6, Berlin.
Richard Broja, Kaiser Wilhelmstrasse, Breslau.
C. E. L. Brown, Messrs Brown, Boveri & Co., Baden.
Prof. Carl Busley, Imperial German Navy, 2 Kronprinzen Ufer, Berlin, N.W.
M. von Dolivo-Dobrowolski, Bruckenallee 23, Berlin, N.W.
W. Fischer, Chief Engineer, Bavarian State Railways, München.
Prof. Oswald Flamm, Goethestrasse 78, Charlottenburg, Berlin.
L. Franzius, Oberbaudirektor der freien Hansestadt, Bremen.
Otto von der Hagen, Kautstrasse 162, Charlottenburg, Berlin.
G. Kapp, 16 Ulmen Allee Westend, Charlottenburg, Berlin.
G. Langner, Bayreutstr. 20, Berlin W.
M. Meyer, Mechanical Engineer, Royal Prussian State Railways, Berlin.
Ludwig Peschect, Oberster Baudirektor, Breslau.
H. Rathenau, Allgemeine Elektricitæts-Gesellschaft, Berlin.
H. Schröder, Director of the Construction Department, Royal Prussian State Railways, Berlin.
Alfred Schultze, Director of the Ministry of Public Works, Berlin.
A. von Siemens, Markgrafen Strasse 94, Berlin.
W. von Siemens, Markgrafen Strasse 94, Berlin.
H. Wedding, Genthinerstrasse 13, Villa C., Berlin W.

HOLLAND.

Netherland Government.

M. Hoogenboom, Bois le Duc, Holland.
H. Wortman, The Hague.

Koninklijh Instituut van Ingenieurs.

J. H. Beucker Andreae, Retired Engineer-in-Chief, R.D.N., The Hague.
H. Enno van Gelder, Director Engineer of the "Maatschappij de Maas," Rotterdam.
R. A. Van Sandick, General Secretary of the Royal Institute of Dutch Engineers, The Hague.

Vereeniging van Gasfabrikanten in Nederland.

J. van Rossum du Chattel, Gas Works, Linnaenstraat, Amsterdam.
N. W. van Doesburgh, Gas Works, Leyden.

A. E. R. Collette, Heemskerkstraat 30, The Hague.
J. F H. Conrad, Van de Spieghel Staat 3, The Hague.
T. van Hasselt, 28 Weespergyde, Amsterdam.
Ritthem van Lambretchsen, Director of Public Works, Amsterdam.
C. L. Loder, Director of Naval Construction, R.D.N., The Hague.
W. Verweij, Chief Engineer, Dutch State Railways, Utrecht.

HUNGARY.

Hungarian Government and Association of Hungarian Engineers and Architects, Budapest.

L. Létay, Nádor-uteza, 32, Budapest V., Ker.
B. Uhlarik, Krisztina-körut, 36, Budapest I.
Professor C. Zipernowsky, Polytechnicum, Oszloputeza, 7, Budapest II., Ker.

O. T. Blathy, Messrs Ganz & Co., Budapest.
Johan Brockh, IX. Bez. Ulloer-Strasse N. 19, Budapest.
Alex. Robitsek, Director of Construction, Hungarian State Railways, Budapest.

INDIA.

Bombay-Baroda, and Central Indian Railway.

E. S. Luard, Locomotive and Carriage Superintendent.

T. C. Deverell, City Engineer, Calcutta.
C. L. Griesbach, C.I.E., Director, Geological Survey of India, Calcutta.
M. C. Murzban, "Gutestan," Murzban Road, Esplanade, Bombay.
R. H. Trevithick, Locomotive and Carriage Superintendent, Great Great Indian Peninsula Railway, Bombay.

ITALY.

Italian Government.

George Breen, Italian Consul General in Glasgow, 240 St. Vincent Street, Glasgow.

Ministero della Marina.

Giorgio Pruneri, Ingegnere Capo del Genio Navale, Roma.

Ministero dei Lavori Pubblici.

Giorgio Pruneri, Ingegnere Capo del Genio Navale, Roma.

Ministero della Agricultura.

Giorgio Pruneri, Ingegnere Capo del Genio Navale, Roma.

R. Corpo della Miniere.

Giorgio Pruneri, Ingegnere Capo del Genio Navale, Roma.

Società delle Conferenze frai Gassisti d'Italia.

Leone Mariani, Direttore Generale della "Società Italiana per il Gaz," Torino.
Luigi Beria, Direttore della "Società Consumatori Gaz Luce," Torino.
Carlo Bourne, Ingegnere in Capo del Gaz, Milano.

Società degli Ingegneri e degli Architetti Italiani.

Mariano Edoardo Canizzaro, 89B via Panisperna, Roma.
Ettore Basevi, 17 via Montecatini, Roma.

Conte A. Betocchi, Ispettore del Genio Civile, Rome.
Prof. Guiseppe Colombo, Milan.

Prof. G. Mengarini, Rome.
P. Orlando, Via Gaeta 2, Roma.
N. Pellati, Servizio Minerario, Ministero d'Agricoltura, Roma.
Lieut.-Col. F. Pescetto, Gio Ansaldo' Genova, per Cornigliano, Ligure.
Major G. Rota, Naval Architect to the Royal It. Navy, Ministero della Marina, Roma.
Charles de Grave Sells, Sampierdarena, Italy.
Col. N. Soliani, Direttore del Cantiere Navale Ansaldo, Sestri Ponente, Genoa.

JAPAN.

Tokio Imperial University, Engineering College.

C. Shiba, 46 Sutherland Avenue, London W.

Viscount Vice-Admiral Enomoto, Tokio.
I. Fujiko, 56 Ziamokubo, Azabu, Tokio.
H. Hara; Tokio University, Japan.
Admiral S. Sasoa, The Admiralty, Tokio.

NORWAY.

Norwegian Government.

M. Saxegaard, Ingénieur de Section, Christiania.
M. Rasmussen, Inspecteur des Télégraphes, Christiania.

Norske Ingeniör-og Arkitekt Forening.

S. Eyde, Christiania.
Einar Rasmûssen, Steners Gaden 8, Christiania.
William R. Pihl, Sannergaden 11, Christiania.

W. H. Carl Swensen, Royal Norwegian Dockyard at Karl Johansvoern, Horten, Norway.
Prof. T. H. L. Vogt, The University, Christiania.

PORTUGAL

Portuguese Government.

J. V. Mendes Guerreiro, Engineer-in-Chief of Public Works, Lisbon.

ROUMANIA.

N. de Lodygensky, President of the European Commission of the Danube; Galatz, Roumania.

RUSSIA.

Ministère des Voies de Communication.

Professor V. E. de Timonoff, 10 rue Bronitzkaïa, St. Petersburg.
Professor Vosnessensky, c/o Ministère des Voies de Communication, St. Petersburg.
M. Emelianow, Moscow-Arkangel State Railway, Moscow.

Institut Imperial des Ingénieurs des Voies de Communication.

Professor V. E. de Timonoff, 10 rue Bronitzkaïa, St. Petersburg.

Prof. Egoroff, St. Petersburg.
Michel Ghercivanof, Zabalkanske 9, St. Petersburg.
Col. E. E. Goulaeff, Chief Naval Constructor, The Admiralty, St. Petersburg.
Vladimir Inchenesky, Moguileff, Province of Podolia.
General N. E. Kouteynikoff, Chief Inspector of Naval Construction, Admiralty, St. Petersburg.
M. Welitschko, Chief of the Traction and Materials Departments, Russian State Railways, St. Petersburg.

SPAIN.

Evaristo de Churruca, Ingeniero Director de las obras del Puerto de Bilbao, Spain.
Mendes Nunez, ; Harbour Engineer, Vigo, Spain.

General Enrico Garcia de Angelo, Director of Naval Construction, Ministry of Marine, Madrid.
Andres A. Comerma, General de los Ingenieros de la Armada, Ferrol.

SWEDEN.

Svenska Technologföreningen.

Oscar Lamm, Atlas Engineering Works, Atlas, Stockholm.
Axel Wahlberg, Tekniska Högskolan, Stockholm.
Martin Borgstedt, Svenska Teknologföreningen, Stockholm.

Dr. Richard Akerman, Chief of the Royal Swedish Board of Trade, Stockholm.
C. Anncrstadt, Librarian, Royal University of Upsala, Upsala.
John Hammar, 32 Wallingatan, Stockholm.
H. H. Lilliehook, Chief Constructor, Swedish Navy, Stockholm.
G. Nordenstrom, late Professor of the Mining School, Stockholm.
Baron Gustaf Tamm, Stockholm.

SWITZERLAND.

Federal Government.

Professor Aurel Stodola, Ecole Polytechnique Fédérale, Zurich.

Société Vaudoise des Ingénieurs et des Architectes, Lausanne.

Edouard Elskes, 37, Boulevard de Corancy, Lausanne.

Schweizerischer Verein von Gas-und Wasser Fachmænnern.

E. Blanc, Administrateur des Travaux Municipaux du Gaz, Geneva, Switzerland.

G. Cuenod, Chief Engineer, Jura Simplon Railway, Lausanne.
A. de Morlot, Inspectorat Federal des Travaux Publics, Berne.
Colonel Huber, President Maschinenfabrik, Oerlikon, Zurich.
A. Schrafl, Chief Engineer, San Gothard Railway, Lucerne.
W. Wyssling, Zurich.

UNITED STATES.

American Institute of Electrical Engineers.

Prof. W. A. Anthony, 313 West 33rd St., New York, N.Y.
Prof. A. Graham Bell, 1331 Conn. Avenue, Washington, D.C.
Prof. H. Carhart, Ann Arbor, Michigan.
Professor F. B. Crocker, Columbia University.

Dr L. Duncan, 71 Broadway, New York.
T. A. Edison, Llewellyn Park, N.J.
Prof. E. J. Houston, Ph.D., 1809 Spring Garden Street, Philadelphia, Pa.
A. E. Kennelly, 1203-4 Crozer Buildings, 1420 Chestnut Street, Philadelphia, Pa.
T. C. Martin, 120 Liberty St., New York City.
G. Revay, Waldorf Astoria, New York.
C. F. Scott, Westinghouse Electric and Manufacturing Co., Pittsburg, Pa.,
F. J. Sprague, Sprague Electric Co., New York City.
Elihu Thomson, Monument Avenue, Swampscott, Mass.
E. Weston, 120 William Street, Newark, N.J.

Engineers' Society of Western Pennsylvania.

Chester B. Albree, 410 Penn Avenue, Pittsburg, Pa.

American Society of Mechanical Engineers.

Sir Benj. Baker, 2 Queen Square Place, Westminster, London, S.W.
O. H. Baldwin, 22a College Hill, Cannon Street, London, E.C.
Philip Dawson, 59 City Road, London, E.C.
Bryan Donkin, Reigate, England.
James Dredge, 35 Bedford Street, Strand, London, W.C.
Prof. F. R. Hutton, 12 West Thirty-First Street, New York.
Rear-Admiral George W. Melville, Navy Dept., Washington, D.C.
Charles H. Morgan, Worcester, Mass.
H. F. L. Orcutt, 30 Farringdon Road, London, E.C.
Horace F. Parshall, 8 Princes St., Bank, London, E.C., England.
Alex. Sahlin, Millom & Askem Hæmatite Co., Millom, Cumberland, England.
Professor William Cawthorne Unwin, Palace Gate Mansions, Kensington, London, W.
Samuel T. Wellman, New England Building, Cleveland, O.

Arthur V. Abbott, 203 Washington Street, Chicago,
Gano S. Dunn, Chief Engineer, Crocker-Wheeler Co., Ampere, New York.
W. L. R. Emmet, General Electric Co., Schenectady, New York.
John Fritz, Bethlehem, Pennsylvania.
Carl Hering, 929 Chestnut St., Philadelphia, Pa.
Abram S. Hewitt, 17 Burling Slip, New York.
J. W. Lieb, Junr., 53 Daune Street, New York.
L. B. Stillwell, Park Row Buildings, New York City.

LIST OF MEMBERS

Members of the General Committee are indicated by the sign +, or by the sign ++ if they are also members of the Reception Committee.

A

680. J. L. Aamundsen, Classensgade 57, Copenhagen, Denmark.
1315. W. P. Abell, Duffield, Derby.
1196. R. G. Abercrombie, Broad Street Engine Works, Alloa.
733. J. M. Adam, 15 Walmer Crescent, Glasgow.
53. J. W. Adam, Ferguslie Villa, Paisley.
633. M. A. Adam, 145 Fordwych Road, W. Hampstead, London, N.W.
1002. A. Adams, 75 Waterloo Street, Glasgow.
1870. G. N. Adams, Mars Iron Works, Wolverhampton.
1869. Percy J. Adams, Mars Iron Works, Wolverhampton.
\+ 207. Prof. W. Grylls Adams, 43 Campden Hill Square, Kensington, W.
1428. H. Adamson, Hyde, Cheshire.
\+ 849. Jas. Adamson, St. Quivox, Stopford Road, Upton Manor, Essex.
1429. J. Adamson, Hyde, Cheshire.
1106. P. H. Adamson, 11 Fairlie Park Drive, Partick.
1040. F. R. Addie, 8 Westbourne Gardens, Glasgow.
872. R. Addie, Calder Park, Baillieston, by Glasgow.
1752. Edgar T. Agius, Grand Hotel, Newcastle-on-Tyne.
2044. Rear-Admiral Ahmed, c/o Schiff und Maschinenban actien Gesellschaft Germania-werft, in Kiel, Germany.
\+ 1154. Geo. Ainsworth, Consett Iron Co., Ltd., Consett.
826. R. Ainsworth, 49 The Crescent, Peel Park, Manchester.
51. Russel Aitken, 116 Piccadilly, London, W.
607. Thos. Aitken, County Buildings, Cupar-Fife.
52. William Aitken, Telephone House, Temple Avenue, London, E.C.
382. J. A. Aiton, 2 Harley Gardens, London, S.W.
2256. John H. Alexander, Dundonald, Kilmarnock.
416. P. Y. Alexander, The Mount. Batheaston, Somerset.
280 Wm Alexander, 4 Kelvinbank Terrace, Sandyford, Glasgow.
451. Wm. Alexander, 15 Hope Street, Glasgow.
406. H. E. Allan, Rathvene, Penarth, S. Wales.
2119. Jas. A. Allan, Allan Line Office, 25 Bothwell Street, Glasgow.
676. Jas. G. Allan, 110 Candleriggs, Glasgow.
1751. William Edgar Allan, Clevedon House, Ranmoor, Sheffield.
1546. Harry Allcard, Albert Works, Sheffield.
1244. Harry Allcock, Peel Terrace, Stretford, Manchester.
10. C. E. Allen, 48 Temple Chambers, Embankment, E.C.
1872. H. Allen, Blast Furnace Power Syndicate, Ltd., 29 Gt. George Street Westminster, London, S.W.
1234. W. H. Allen, Queen's Engineering Works, Bedford.
++ 2344. S. E. Alley, Sentinel Works, Polmadie Road, Glasgow.
2032. Hy. T. Allison, 13 Granville Road, Newcastle-on-Tyne.
656. Wm. Allison, Mansfield Cottage, Kilwinning.
315. C. S. Allott, 46 Brown Street, Manchester.
++ 748. W. M. Alston, 24 Sardinia Terrace, Hillhead, Glasgow.
503. F. T. Aman, 55 Church Street, Birkenhead.
1533. R. Ames, 116 Loughborough Road, West Bridgeford, Nottingham.
2326. E. Chas. Amos, East Dean, Grange Road, Sutton, Surrey.
1215. A. Anderson, Greenbill House, Dunaskin, by Ayr.
1453. E. E. J. Anderson, Gas Works, Ripon.

1005. F. Carleton Anderson, 53 Bothwell Street, Glasgow.
1921. G. W. Anderson, Gas Works, Whyteleafe, Surrey.
1044. Jas. Anderson, 212 Renfrew Street, Glasgow.
2163. Jas. Anderson, 1 Marlborough Terrace, Glasgow.
2157. J. Godfrey Anderson, 2 Park Place, Bothwell.
++ 1360. Jas. H. Anderson, 34 Lansdowne Crescent, Glasgow.
523. Robt. S. Anderson, Benwell View, Bentwick Road, Newcastle-on-Tyne.
1365. Thos. Anderson, c/o J. Lockie, Esq., 2 Customhouse Chams., Leith.
1267. W. Graeme Anderson, 31 Enfield Place, Motherwell.
1716. David Andrew, 33 Osborne Road, Newcastle-on-Tyne.
732. Jas. Andrews, Eton Villa, Rhannan Road, Cathcart.
1233. Sidney Andrews, 28 Blythswood Drive, Glasgow.
256. W. J. Angus, 79 Greengate Street, Barrow-in-Furness.
1695. John Anstee, Chellow Drive, York Road, Guildford, Surrey.
905. H. W. Appleby, c/o Gibbings & Baker, Old Bank Chambers, Bradford.
54. P. V. Appleby, 27 Lincoln Street, Leicester.
930. G. N. Aranghy, 20 Kelvingrove Street, Glasgow.
1753. H. Archibald, Dalzell Iron and Steel Works, Motherwell, N.B.
333. Lt.-Col. F. H. Armstrong, Gilnockie, East Southsea, Hants.
957. F. W. Arnold, 19 Cross Street, Chesterfield.
290. Wm. Arnot, 79 W. Regent Street, Glasgow.
1148. L. J. Aron, 46 Upper Thames Street, London, E.C.
++ 1274. Sir Wm. Arrol, Seafield, Ayr.
++ 1160. T. A. Arrol, Germiston Works, Petershill, Glasgow.
1166. A. S. D. Arundel, Penn Street Works, Hoxton, London, N.
1754. A. J. Ash, Great Bridge, Tipton, Staffs.
1235. Thomas Ashbury, Ash Grove, Victoria Park, Manchester.
428. F. W. Ashcroft, 11 Park Street, Lytham.
2027. John Ashford, 27 Baronsmere Road, East Finchley, London, N.
1142. J. D. Ashworth, 7 Wharf Road, Mile End, Portsmouth.
1755. W. H. Ashworth, Bollam Works, Retford.
+ 1067. Jno. A. F. Aspinall, Gledhill, Sefton Park, Liverpool.
555. Wm. Aspinall, Rockleigh, Ashton-in-Makerfield, Lancs.
1402. E. A. Aston, 18 S. Sackville Street, Dublin.
1633. A. F. T. Atchison, Holmwood, Four Oaks, Nr. Birmingham.
1871. Samuel Atherton, 11 Annwood Colliery, Shrewsbury.
660. A. Atkinson, c/o Messrs. Babcock & Wilcox, Ltd., 17 The Exchange, Middlesbro'.
642. Alex. John Atkinson, 24 Waterloo Road, Newport, Mon.
983. F. R. Atkinson, Congleton, Cheshire.
542. John Atkinson, Borough Surveyor, Stockport.
++ 124. J. B. Atkinson, 18 Merchiston Gardens, Edinburgh.
536. W. N. Atkinson, Barlaston, Stoke-on-Trent.
1756. William Atkinson, Erwood, Beckenham, Kent.
1050. Jabez Attwood, Hagley Road, Stourbridge
89. Arthur C. Auden, Bewdley, Worcester.
2007. John Auld, Rockmount, 13 Broompark Drive, Dennistoun.
1268. W. R. Austin, 11 University Avenue, Glasgow.

B

1115. John T. Babtie, Moss Cottage, Dumbarton.
2008. Walter J. Bache, Electricity Works, Gloucester.
534. James Bailey, 3 South Avenue, Ryton-on-Tyne.
723. J. D. Bailie, 23 Park Row, Leeds.

1757. Robert Baillie, 95 Bath Street, Glasgow.
843. Jas. Bain, The Whins, Alloa, N.B.
868. W. B. Bain, 65 Waterloo Street, Glasgow.
679. Wm. N. Bain, 40 St. Enoch Square, Glasgow.
2112. Geo. S. L. Bains, Surveyor, Saltburn-by-the-Sea.
770. A. W. Baird, 30 St. Andrews Drive, Pollokshields, Glasgow.
954. A. W. Baird, 4 Queen Margaret Crescent, Glasgow.
++ 1298. James Baird, Kinneff, Prestwick, Ayrshire.
1883. Matthew B. Baird, West House, Bothwell.
463. C. E. Baldwin, 2 North Road, Darlington.
532. Alfred J. Balkwill, Phœnix House, Calder Vale Road, Wakefield,
1596. William Ball, jun., Cragside, Torquay, S. Devon.
163. J. Ballantyne, Gas Works, Hamilton.
2009. Thos. Ballantyne, 5 Saltoun Gardens, Kelvinside.
1717. David Ballingall, 33 Dudley Crescent, Newhaven Rd., Edinburgh.
312. Henry K. Bamber, Westminster Chambers, 9 Victoria Street, London, S.W.
1662. Harry Bamford, 3 Albany Street, Glasgow.
995. F. J. Bancroft, Town Hall, Hull.
1449. A. Banister, Kirkstall Forge, Leeds.
55. A. N. Banister, 8 Oxford Hill, Norwich.
164. T. W. Barber, Ottershaw, Surrey.
1758. George Barclay, Vulcan Works, Paisley.
1261. Wm. R. Barclay, 87 James Street, Rotherham.
1880. Charles D. Barker, 231 St. Vincent Street, Glasgow.
1398. A. B. Barlow, 6 Trafford Place, Stretford Rd., Manchester.
1718. Harry D. D. Barman, 27 University Avenue, Glasgow.
1193. J. R. Barnett, Westfield, Crookston.
1124. M. R. Barnett, Laurel Bank, Lancaster.
2028. Patrick M. Barnett, Ivy Lodge, 2 Westfield Terrace, Aberdeen.
++ 2013. Prof. Arch. Barr, Royston, Dowanhill, Glasgow.
++ 1281. John Barr, Glenfield Works, Kilmarnock.
++ 1719. P. G. Barr, Machan Hill, Larkhall.
2351. Thos. Barr, West Hartlepool.
1765. W. Barrington, Clare Chambers, Limerick.
2168. James Barron, 1 Bon-Accord Street, Aberdeen.
1721. James Barrow, Maestry, Glam.
1876. Joseph Barrow, Union Iron Works, Johnstone.
313 Louis Barrow, Clovelly, Kings Norton.
++ 88. James Barrowman Staneacre, Hamilton.
1393. Wm. Barrowman, Ayr View, Muirkirk.
+ 255. Sir J. Wolfe Barry, K.C.B., 21 Delahay Street, London, S.W.
56. J. Barton, Dundalk.
411. John J. Barton, 1 St. Thomas Street, Ryde.
431. Thomas Barty, 218 W. Regent Street, Glasgow.
1722. C. O. Bastien, Bartholomew Works, End of Lawford Road, Kentish Town, London.
11. A. H. Bate, 214 Soho Road, Handsworth, Birmingham.
437. James R. Baterden, 54 Brighton Grove, Newcastle-on-Tyne.
1759. Henry Bates, 30 Trafford Road, Salford, Manchester.
1541. Fred Bathurst, 6 Loudoun Road, London, N.W.
902. H. Bauerman, 14 Cavendish Road, Balham, London, S.W.
1069. R. F. Baxandall, Cregneish, Ben Rhydding, Yorkshire.
948. And. Baxter, Engineer, Coatbridge.
1882. Geo. H. Baxter, Helenslea, Dalmuir.
1109. P. MacLeod Baxter, 181 Pitt Street, Glasgow.
226. Captain F. Bayley, 4 Staff Quarters, Brompton Barracks, Chatham.
2288. Thos. A. Bayliss, Kings Norton.

423. T. R. Bayliss, Belmont, Northfield, near Birmingham.
264. D. C. Beadon, Stoneham, Beechgrove Road, Newcastle-on-Tyne.
372. G. H. T. Beamish, Spyhill House, Queenstown, Ireland.
++ 1408. Geo. Beard, Maristuen, Stepps.
12. Herbert Beard, Gartcosh, near Glasgow.
++ 2058. W. Beardmore, Parkhead Rolling Mills, Glasgow.
1884. Wm. Frederick Beardshaw, Baltic Steel Works, Sheffield.
2091. L. Beaujeu, Prof. at the Technical School of Naval Construction, Paris.
1063. C. W. Beckwith, 25 Southfield Road, Middlesbrough, Yorkshire.
1601. J. Phillips Bedson, Newton House, Hyde.
262. W. T. Beesley, 42 Norfolk Road, Sheffield.
1343. Wm. Begg, 34 Belmont Gardens, Hillhead.
33. F. B. Behr, 5 Queen Anne's Gate, Westminster, London, S.W
++ 1570. George T. Beilby, 8 University Gardens, Glasgow.
295. David Bell, 19 Eton Place, Hillhead, Glasgow.
7. Imrie Bell, 49 Dingwall Road, Croydon.
2108. J. Ferguson Bell, 4 The Gables, Uttoxeter New Road, Derby.
1602. Leo. M. Bell, Huntly, Bangor, Down.
+ 1760. Sir Lowthian Bell, Rounton Grange, Northallerton.
1723. Norris G. Bell, c/o J. Wilkie, Esq., Oakden, Falkirk.
125. Stuart Bell, 65 Bath Street, Glasgow.
2233. W. J. Belsey, c/o British Thomson-Houston Co., Rugby.
429. D. Bennett, 36 Hawthorn Road, Failsworth, Manchester.
2192. M. H. Bennett, The Chestnuts, Brighton Road, Horley.
1208. P. M. Bennett, Tewcliff, Grange-over-Sands.
699. H. O. Bennie, 6 Camphill Drive, Crosshill, Glasgow.
32. D. E. Benson, 18 Lansdowne Road, Southport.
1761. R. Seymour Benson, Messrs. Ashmore, Benson, Pease & Co., Ltd. Stockton-on-Tees.
790. G. N. Bentley, 13 Morley Street, Newcastle-on-Tyne.
90. Thomas Berridge, Gas Works, Leamington.
2250. Walter Best, 51 Brougham Street, Greenock.
2342. Alwin Beugger,
2003. Robt. Beveridge, Jun., 19 Polmuir Road, Aberdeen.
959. R. R. Bevis, Vyner Road, Birkenhead.
358. Hubert Bewlay, The Lindens, Moseley, Birmingham.
1655. Manuel Bianchi, Estado Mayor de Marina, Buenos Aires, Argentine Republic.
++ 805. A. S. Biggart, Dalmarnock Iron Works, Glasgow.
630. J. L. Biggart, Woodbine, Bridge of Weir.
++ 1004. D. Selby Bigge, 53 Bothwell Street, Glasgow.
126. C. H. W. Biggs, Glebe Lodge, Champion Hill, London, S.E.
++ 2057. Prof. J. H. Biles, The University, Glasgow.
1070. John E. Bingham, West Lea, Sheffield.
1960. J. C. Binks, Norchard Colly., Sydney, Glos.
1600. Sir Alex. R. Binnie, 77 Ladbrook Grove, Notting Hill, London, W.
2339. Robt. Birkett, Boro' Electric Engineer, Burnley, Lancs.
1623. Alex. Bishop, Engineer's Office, Buchanan Street Station, Glasgow.
1249. J. Fred Black, Lagarie, Row, Dumbartonshire.
1134. J. W. Black, 51 Montgomerie Street, Kelvinside, N., Glasgow.
1337. R. S. Black, Mansfield, Tayport.
1314. Thos. Black, Spennymoor.
2098. Wm. Black, 11 Howard Street, Arbroath, N.B.
34. A. B. Blackburn, New Oxley, Wolverhampton.
260. G. R. Blackburn, 5 Swinton Place, Horton, Bradford.
1221. S. Blackley, Marchhill, Dumfries.
1881. G. G. Blackwell, The Albany, Liverpool.

1406. R. G. Blaine, Bannview House, Rathfriland, Co. Down, Ireland.
913. Frank R. Blair, Ashbank, Maryfield, Dundee.
779. Geo. Blair, jun., 4 Kinnoul Place, Dowanhill, Glasgow.
1102. Geo. Blair, 16 Albert Road, E., Crosshill, Glasgow.
++ 2206. Jas. MacLellan Blair, Williamcraigs, Linlithgow.
1019. R. Blair, Dunwood, Dumbarton.
1508. George R. Blake, 134 St. Vincent Street, Glasgow.
696. Matthew Blake, 62 Forsyth Street, Greenock.
575. A. R. Bleayard, Boro' Surveyor, 46 York St., Clitheroe, Lancs.
1132. C. E. Bloomer, Haywood Forge, Halesowen.
2113. John Blue, Assuan, Egypt.
113. S. R. Blundstone, 3 Ludgate Circus Buildings, London, E.C.
++ 2056. B. Hall Blyth, 17 Palmerston Place, Edinburgh.
373. Chas. L. Boddie, Co. Surveyor's Office, Londonderry.
1197. Albert Boissiere, 124 Boulevard Magenta, Paris.
1762. E. Bond, c/o Messrs. J. C. Abbott & Co., Corporation St., B'ham.
1116. C. R. Bonn, Elmbank, Bowling, N.B.
1878. Arthur Booth, Union Foundry, Rodley, Leeds.
1877. John Wm. Booth, Union Foundry, Rodley, Leeds.
283. R. Bell Booth, 4 Ellerslie Villas, Bray, Wicklow.
601. H. Borns, 19 Alexandra Road, Wimbledon, London, S.W.
1399. P. Borrie, 4 Oxford Terrace, Norton Road, Stockton-on-Tees.
583. W. C. Borrowman, Newstead, West Hartlepool.
2296. Walter Bosman, 26 Victoria Street, Westminster, S.W.
1187. W. D. A. Bost, Adelphi House, Paisley.
155. Sam Boswell, 82 Albert Grove, Longsight, Manchester.
1988. Chas. F. Botley, Guildables, Hastings, Sussex.
1764. James Bott, Rose Lea, Eaglescliffe, R.S.O.
650. Walter Stanley Bott, c/o Messrs. A. Ransome & Co., Ltd., Newark-on-Trent.
++ 1280. James T. Bottomley, 13 University Gardens, Glasgow.
2260. Prof. Jules Boulvin, Ghent, Belgium.
286. L. Bourgoignie, 7 Rue de Bruxelles, Termonde, Belgium.
1724. Harold V. Bower, Ivy House, Higher Openshaw, Manchester.
2224. Wm. A. Bower, Loescoe, Grange, Normanton.
2366. Wm. T. Bowen-Jones, Bronala, Carnarvon.
1017. Arthur Bowes, Wargrave Cottage, Newton-le-Willows, Lancaster.
1139. W. D. Bowman, 21 Kersland Terrace, Hillhead, Glasgow.
++ 2261. Chas. H. Bowser, 80 Charles Street, St. Rollox, Glasgow.
1344. Edw. Box, 9 Washington Terrace, N. Shields.
1099. J. C. Boyd, 40 Aglionby Street, Carlisle.
334. Cyrus Braby, "Slynfolde," Sutton, Surrey.
634. C. E. Brackenbury, Continental Union Gas Co., 7 Drapers Gardens, London, E.C.
486. W. L. Bradley, The Castle, Tonbridge, Kent.
91. George G. Braid, 100 Bothwell Street, Glasgow.
2249. Chas. Bramall, Caledonian Works, Oughtibridge.
++ 1161. James Brand, 10 Marchmont Terrace, Kelvinside.
1646. Jas. Brash, c/o E. Scott & Mountain, Ltd., 93 Hope St., Glasgow.
824. Geo. J. Bray, Chipping Sodbury, Glos.
2194. John H. Brearley, Engineer, Longwood, Huddersfield.
625. Alan Brebner, 10 Hereford Road, Acton, London, W.
+ 329. C. A. Brereton, 21 Delahay Street, Westminster, S.W.
730. S. E. Bretton, Electricity Works, Motherwell.
1028. J. Alfred Brewer, 249 West George Street, Glasgow.
488. J. H. Brierley, Town Hall, Richmond, Surrey.
330. Philip Bright, Hadley, Barnet.
204. Wm. Bright, Noyaddfach, Pontardulais, R.S.O.

569. Prof. A. W. Brightmore, Egham Hill, Egham, Surrey.
1479. Frank Broadbent, 27 Devonshire Place, Newcastle-on-Tyne.
1345. H. Broadbent, Edgerton Grove, Huddersfield.
378. A. E. Broadberry, Elmlea, Willoughby Lane, Tottenham.
1725. Jas. Broadfoot, Lymehurst, Jordanhill.
665. Wm. R. Broadfoot, Inchnolm Works, Whiteinch.
2045. John W. Broadhead, The Hollies, Elland, Yorks.
1328. G. Broadrick, Broughton House, Broughton Road, Ipswich.
1072. B. J. Broadway, 267 Hagley Road, Edgbaston, Birmingham.
812. H. W. Brock, Engine Works, Dumbarton.
2282. John A. Brodie, City Engineer, Liverpool.
1466. J. B. Brodie, Millburn House, Largs.
2333. Wm. Brodie, Dockyard, Liverpool.
1727. Alfred H. Brookman, Gas Works, Tenby, South Wales.
1879. M. M. Brophy, 48 Gordon Square, London, W.C.
+ 1765. Bennett H. Brough, Secretary, Iron and Steel Institute, 28 Victoria Street, London, S.W.
++ 1720. Adam Brown, Wellbank Cottage, Ferniegair, Hamilton.
++ 1015. And. Brown, Castlehill, Renfrew.
363. A. M'N. Brown, "Strathclyde," Dumbreck, Glasgow.
1728. Arthur R. Brown, 13 Lime Street, London, E.C.
2130. Geo. J. C. Brown, 2 Stanley Villas, Seascale, Vîa Carnforth.
1150. John Brown, Longhurst, Dunmurry, Belfast.
883. J. H. Brown, 30 Argyle Road, Ilford, E.
945. J. P. Brown, 2 Parkgrove Terrace, Glasgow, W.
1181. M. T. Brown, 34 Gray Street, Glasgow.
+ 1699. M. Walton Brown, Secretary, The Institute of Mining Engineers, Newcastle-on-Tyne.
127. Peter B. Brown, 22 Osgathorpe Road, Sheffield.
645. Richard Brown, Fairlight, Glisson Road, Cambridge.
2149. Richard Brown, Glenmore, The Avenue, Southampton.
2129. T. J. Brown, 233 St. Vincent Street, Glasgow.
395. Wm. Brown, Meadowflat, Renfrew.
673. Wm. Brown, 3 Midlothian Drive, Shawlands.
1068. W. P. Brown, 5 Cromwell Square, Queen's Park, Glasgow.
385. R. F. Browne, 19 Grove End Road, St. John's Wood, London. N.W.
1875. John J. Brownhill, 98 North Walsall, Walsall.
1874. William Brownhill, Vesey Grange, Mancy Sutton Coldfield, Warwick.
960. Chas. Brownridge, Town Hall, Birkenhead.
2286. Captain J. Bruce-Kingsmill, R.A., The Ordnance College, Woolwich.
++ 595. John Bryce, 17 Peel Street, Partick.
210. Henry Bryer, 1 Miskin Road, Dartford.
1873. D. R. Bryson, 45 Hope Street, Glasgow.
1260. Wm. Bryson, 4 Windsor Street, Dundee.
218. Walter Buchanan, Clyde Iron Works, Glasgow.
1690. Edward Buckham, Town Hall, Ipswich.
2334. J. Buckley, Gas Works, Formby.
578. C. F. Budenberg, Somerville, Marple, Cheshire.
2265. Edw. P. Bullard, Jun., Bridge Port, Conn., U.S.A.
381. E. H. E. Bulwer, 4 Clarence Terrace, Grimsby.
++ 1631. Henry Bumby, Burgh Boundary, Wishaw.
245. W. J. Bumiley, Beech-Hurst, Chorley New Road, Bolton.
966. T. F. Bunting, Borough Surveyor, Maidstone.
1265. Herbert T. Burls, 84 Lee Road, Blackheath, London, S.E.
2197. J. Morison Burnup, 77 Carlisle Mansions, Victoria St., London, S.W.
1766. W. Burnyeat, Millgrove, Moresby, Whitehaven.
++ 2055. Councillor Burrell, 54 George Square, Glasgow.
1074. H. R. J. Burstall, 14 Old Queen Street, Westminster, London, S.W.

++ 1127. Thos. Burt, 60 St. Vincent Crescent, Glasgow.
749. J. S. Burton, Orrell, Wigan.
2146. Wm. Burton, Maxwell House, Wigan.
128. Walter E. Butcher, 18 Brixton Road, Brighton, Sussex.
1451. Edmund Butler, Kirkstall Forge, Leeds.
1450. H. M. Butler, Kirkstall Forge, Leeds.
2279. Isaac Butler, Pantee House, Nr. Newport, Mon.
2291. James Butler, Victoria Ironworks, Halifax.
1729. J. P. J. Butler, 26 Craven Park, Willesden, London.
1177. J. S. Butler, 21 Hamilton Terrace, Partick, Glasgow.
510. T. F. Butler, Infield, Barrow-in-Furness.
1527. W. J. A. Butterfield, 66 Victoria Street, London, S.W.
1457. J. Butterworth, Thorn Cottage, Pendlebury, Manchester.
14. W. L. Byers, 11 Norfolk Street, Sunderland.
901. A. R. Byles, "Observer" Office, Bradford.
269. St. Clare Byrne, 48 Castle Street, Liverpool.

C

++ 2319. H. M. Cadell, Grange, Bo'ness.
+ 2188. James C. Cadman, Silverdale, North Staffordshire.
481. Thomas Caink, Sunny Bank, Fort Royal Hill, Worcester.
480. T. G. Caink, Sunny Bank, Fort Royal Hill, Worcester.
++ 1577. Patrick T. Caird, Belleaire, Greenock.
++ 638. Robert Caird, 56 Esplanade, Greenock.
298. Charles W. Cairns, 4 Hollow Lane, Barrow-in-Furness.
202. Wm. T. Calderwood, Stanley Villa, Cathcart.
2375. Frederico Camara, Rio de Janeiro, Brazil.
2303. D. Cameron, City Surveyor, Exeter.
850. John B. Cameron, Lochiel, Bearsden.
1251. Duncan Campbell, Knock, Partickhill.
1469. G. Campbell, 34 Orrell Lane, Aintree, Liverpool.
1767. James Campbell, c/o Wild & Co., Middlesbrough-on-Tees.
216. Thomas Campbell, Maryhill Iron Works, Glasgow.
1359. Wm. W. Campbell, Oakshawhead House, Paisley, N.B.
129. A. Campion, Cooper's Hill, Englefield Green, Surrey.
2347. Rev. G. M. Capell, Passenham, Stone, Stratford.
1368. Professor D. S. Capper, 17 Victoria Street, London, S.W.
+ 265. Sir E. H. Carbutt, Bart., Nanhurst, Cranleigh, Surrey.
165. Lieut. A. D. Carden, St. Mary's Barracks, Chatham, Kent.
1650. E. G. Carey, 4 Sunnyside Avenue, Uddingston.
1383. Alex. L. Carlaw, 14 Fitzroy Place, Glasgow.
1382. D. Carlaw, jun., 10 Randolph Gardens, Glasgow.
1625. Wm. H. Carlaw, jun., 5 Foremount Gardens, Glasgow.
1768. E. Carlisle, Inspecting Engineer, 96 Clifton Hill, St. John's Wood, London, N.W.
1011. R. S. Carlow, Gas Works, Arbroath.
1525. J. Carmichael, Stair Cottage, Barrhead.
874. Wm. Carnegie, 90 Eglinton Road, Plumstead, London, S.E.
2325. Edw. C. Carnt, St Heliers, Cowes, Isle of Wight.
+ 1665. Charles Carpenter, 709a Old Kent Road, London, S.E.
933. John M. Carr, 7 Woodhall Drive, Cardonald.
247. Henry Carrick, Hallgarth, Darlington.
248. H. H. Carrick, 10 Clarendon Place, Leeds.
254. J. Carruthers, 19 Kensington Park Gardens, London, W.
364. J. H. Carruthers, 38 Queen Mary Avenue, Glasgow.
1481. Robert Carson, Minerva Chambers, Hull.

962. S. J. Carstens, c/o Messrs. Burmeister & Wain, Copenhagen.
1674. Charles J. Carter, 3 Quarrington Road, Horfield, Bristol.
2141. Douglas R. Carter, 141 Bath Street, Glasgow.
86. George F. Carter, Town Hall, Croydon.
1730. Wm. A. Carter, 5 St. Andrew Square, Edinburgh.
1673. Joseph Cartmell, M. & C. Railway, Maryport.
+ 794. J. Cartwright, Albion Place, Bury, Lancashire.
2148. John T. Cartwright, 101 Armadale Street, Dennistoun, Glasgow.
1564. Prof. C. A. Carus-Wilson, Mill View House, Sutton-on-Sea, Linc.
388. Thos. A. B. Carver, 118 Napiershall Street, Glasgow.
1571. R. D. Cassells, 168a St. Vincent Street, Glasgow.
989. J. M'I. Cater, Southdown, Wimbledon.
1769. Geo. Cawley, 29 Great George Street, Westminster, London, S.W.
490. John F. Cay, Knowle Lodge, Lichfield.
515. Wm. D. Cay, 1 Albyn Place, Edinburgh.
328. John R. Chalmers, 18 Hemingford Road, London, N.
1223. Walter Chalmers, 24 Claremont Gardens, Milngavie.
++ 1035. Wm. A. Chamen, Drumard, Partickhill Road, Glasgow.
2245. P. Chamfraull, Sauhier, Met. M., France.
899. Noel Chandler, Cannock, Staffs.
566. J. L. Chapman, The Haven, Wembley, Middlesex.
114. A. G. Charleton, Dashwood House, New Broad Street, E.C.
647. G. Chatterton, 6 The Sanctuary, Westminster, London, S.W.
1638. Samuel Chatwood, Broadoak Park, Worsley, Manchester.
1515. Wm. T. Cheesman, 4 Bridgeford Road, Nottingham.
2335. E. D. Chester, 120 Bishopsgate Street Within, London.
2331. W. R. Chester, Nottingham.
2167. Robt. Chisholm, Ferniehirst, Springboig, Shettleston.
2377. The Hon. Lord Provost Samuel Chisholm, City Chambers, Glasgow.
971. R. Chorley, 15 Mile End Lane, Stockport.
771. George Christison, Cremona, Cambridge Drive, Glasgow.
521. Wm. G. Chubb, Brandhaur, Ludlow.
590. G. D. Churchward, Metropolitan Railway Carriage & Wagon Co., Satley Works, Birmingham.
737. Alex. Clark, 11 Blacket Place, Edinburgh.
714. H. A. Clark, 4 Cloberry Street, Leeds.
++ 1892. James A. Clark, Annbank.
877. John Clark, Ormiston, East Lothian.
1770. Robert Clark, 255 Cromwell Road, Kensington, London, S.W.
662. Wm. Clark, jun., 10 Prospect Terrace, Aberdeen.
635. Wm. Clark, 208 St. Vincent Street, Glasgow.
++ 765. W. Clark, Steel Coy. of Scotland, 23 Exchange Square, Glasgow.
1409. J. H. Clarke, Monkbridge Iron Works, Leeds.
831. J. Clarkson, 719 Shields Road, Pollokshields.
2362. George W. Claussen, Gestemunde, Germany.
2107. Fred T. Clayton, Borough Engineer, Reigate, Surrey.
92. Fred Cleeves, 4 Whitehall Court, London, S.W.
908. Alex. Cleghorn, 10 Whittingehame Drive, Kelvinside, Glasgow.
387. Dugald Clerk,41 Bedford Square, London, W.C.
93. G. B. Clifton, 17 Culmington Road, Ealing, W.
692. W. P. Clyde, 42 Clyde Place, Glasgow.
1420. Jas. Clyne, Rubislaw Den South, Aberdeen.
815. A. Coats, jun., Hayfield, Paisley.
1498. James Coats, "Talara," Katharine Drive, Govan.
35. P. R. Cobb, Foyers, N.B.
++ 2135. John Cochrane, Eastpark, Barrhead.
+ 719. R. Cochrane, H.M. Board of Works, Dublin.
464. R. Cockburn, Pennoxstone Court, Ross, Hertfordshire.

2042. Robert Cockburn, Cumbrae House, Dumbreck, Nr. Glasgow.
1122. John Cocks, Brook Side, Romiley, Stockport.
2201. J. W .A. Cocksedge, Eagle Foundry, Ipswich.
+ 1700. Thomas Cole, 11 Victoria Street, London, S.W.
1347. H. R. Coles, Gas Offices, Plymouth.
483. A. Colley, c/o Messrs. A. Hickman, Ltd., Bilston.
725. A. J. Collin, Chief Engineer, Cambrian Road, Oswestry, Salop.
6. William Collingwood, Newton-le-Willows, Lancs.
+ 166. Arthur E. Collins, Guildhall, Norwich.
1489. Wm. B. Collis, Swinford House, Stourbridge.
1490. Walter T. Collis, Swinford House, Stourbridge.
626. H. G. Colman, 27 Stirling Road, Edgbaston, Birmingham.
793. Wm. Colquhoun, Grove Road, Wrexham.
1224. A. Colson, Gas Office, Leicester.
++ 1893. Archibald Colville, Dalzell Steel and Iron Works, Motherwell.
130. David Colville, Jerviston House, Motherwell.
++ 115. Charles Connell, Scotstoun Shipyard, Whiteinch.
1771. J. O. Connell, Editor "Coal and Iron," Coal Exchange, London.
1201. B. Conner, 9 Scott Street, Glasgow.
1258. J. Conner, 4 Clark Street, Kilmarnock.
94. James Conner, L.D. and E.C. Railway, Tuxford, Notts.
1324. E. G. Constantine, 17 St. Anne's Square, Manchester.
+ 1118. John Cook, Town Hall, Lancaster.
915. Jos. Cook, The Poplars, Codnor Park, Alfreton.
1403. J. W. Cook, Binchester Hall, Bishop Auckland, Co. Durham.
1387. Samuel Cook, Albert Works, Bury, Lancashire.
1731. Thos. Cook, Washford Road, Sheffield.
402. R. T. C ooke, 889 Ashton Old Road, Manchester.
2158. Albert J. Coombes, 20 Cross Street, Ryde, I.W.
2368. C. H. Cooper, 63 Queen's Road, Wimbledon.
++ 2085. David Cooper, 10 St. Andrew's Drive, Pollokshields.
251. J. Cooper, Park House, Jarrow-on-Tyne.
+ 1701. R. Elliot Cooper, 8 The Sanctuary, Westminster, London, S.W.
1312. T. L. Read Cooper, 12 Queen's Terrace, Glasgow.
36. W. R. Cooper, Gas Works, Banbury, Oxon.
+ 1065. W. R. Cooper, 87 Upper Tulse Hill, London, S.W.
++ 1889. S. G. G. Copestake, 40 Queen Mary Avenue, Crosshill, Glasgow.
++ 2062. W. R. Copland, 146 W. Regent Street, Glasgow.
1455. Lucien Corbeaux, Ingénieur des Ponts et Chaussées, Cambrai, France
5. Joseph Corbett, Burgh Engineer, Salford.
1886. M. Corby, 13 Montague Road, Edgbaston, Birmingham.
934. A. C. Cormack, 241 Monton Road, Monton, Nr. Manchester.
2000. Prof. J. D. Cormack, University College, London, W.C.
1726. John T. Corner, H.M. Dockyard, Portsmouth.
1077. T. Cosser, Karachi, India.
1772. Edwin Cottam, Bute Steel and Spring Works, Cardiff.
95. A. P. I. Cotterell, Woodcroft, Sneyd Park, Nr. Bristol.
+ 243. S. B. Cottrell, 31 James Street, Liverpool.
1599. W. Arthur Coulson, 40 Ashton Gardens, Glasgow.
1540. J. D. C. Couper, 65 Talbot Street, Grangemouth.
++ 565. S. Couper, Moore Park Boiler Works, Govan.
++ 2223. W. T. Courtier-Dutton, 151 St. Vincent Street, Glasgow.
2277. F. S. Courtney, Broad Sanctuary Chambers, Westminster, S.W.
806. D. Cowan, Clevedon, Cove, Dumbartonshire.
1773. John Cowan, 68 Albert Street, Leith Walk, Edinburgh.
1226. J. Cowan, 179 W. George Street, Glasgow.
240. J. M. Cowan, 6 Salisbury Road, Edinburgh.
323. P. C. Cowan, Chief Engineering Inspector, Dublin.

2034. Wm. Cowie, 25 Baird Street, Coatbridge.
2179. Jas. Cowley, 4 St. Clair Terrace, Morningside Drive, Edinburgh.
1033. Wm. Cowley, Beaumont Terrace, Spennymoor.
1588. Robt. M. Cowper, 3 Queen's Road, Brentwood, Essex.
2. S. O. Cowper Coles, 46 Morpeth Mansions, Westminster, S.W.
1136. A. F. Craig, Caledonian Engine Works, Paisley.
1774. George B. Craig, c/o Messrs. Craig, Taylor & Co., Stockton-on-Tees,
747. James Craig, Netherlea, Partick, Glasgow.
1732. Alex. C. Cramb, Electricity Works, Lithos Road, Hampstead, Lond.
1888. Ellis H. Crapper, 32 Springhill Road, Sheffield.
1775. Jas. Crawford, Hematite Iron Works, Harrington, Cumberland.
+ 704. Alfred Creer, 1 Clifton, York.
1111. H. T. Crewe, 17 Sunning Hill Road, Lewisham, London, S.E.
221. A. H. Crichton, Castlepark, Linlithgow.
1179. David Crichton, 6 Duncan Street, Newington, Edinburgh.
1348. Hugh Crichton, Bute House, Airdrie.
844. James L. Crichton, 3 East Park Terrace, Maryhill.
343. Arthur J. Cridge, 16 Hindham Road, Upper Tooting, London, S.W.
910. Jas. Crighton, 1 Thornwood Terrace, Partick, W.
1556. W. Crockatt, 21 Hope Street, Glasgow.
2244. Walter Crooke, Sen., Millom, Cumberland.
1891. A. W. Crookston, 188 St. Vincent Street, Glasgow.
1418. J. F. L. Crosland, Belcombe, Hale, Altrincham.
764. F. W. Cross, Gas Works, Leyton, Essex.
37. J. R. Cross, Netherton House, Wishaw.
2170. Joseph H. Crossley, Thornhill Lees, Dewsbury.
970. John Crow, 236 Nithsdale Road, Pollokshields.
2287. A. D. Crowther, Wardwick, Derby.
711. G. H. Crowther, Thornhill, Edgerton, Huddersfield.
1776. John Crum, Askam-in-Furness, Lancashire.
613. W. R. Cummins, 15 Victoria Street, Loughboro', Leicester.
1530. D. M. Cunningham, Mill Road, Bathgate.
1202. Hugh Cunningham, Calthorpe Lodge, Banbury.
1590 Peter Cunningham, jun., Easterkennyhill House, Cumbernauld Rd.
1591. Peter N. Cunningham, Easterkennyhill House, Cumbernauld Rd.
2166. Wm. Currie, Gas Works House, Alexandria, N.B.
822. A. E. Curry, 28 Deansgate, Manchester.
506. M. Curry, University College, Bristol.
1138. Jos. C. Custodis, St. Maries Chambers, Norfolk Row, Sheffield.
++ 836. Wm. Cuthill, Beechwood, Uddingston, Glasgow.
1890. Henry A. Cutler, Municipal Buildings, Cork.

D

+ 1702. Robert W. Dana, 5 Adelphi Terrace, London, W.C.
1603. E. L. Daniel, 6 St. James Gardens, Swansea.
15. Thomas Danks, Barrow-in-Furness.
2304. H. W. Darbishire, Plas Mawr, Pemmaenmawr.
808. John Darroch, 27 South Kinning Place, Glasgow.
131. Frank Davenport, Gilda Brook, Eccles.
+ 185. Henry Davey, 3 Princes Street, Westminster, London, S.W.
560. C. J. Davidson, Lloyd's Register, Water Street, Liverpool.
1421. D. Davidson, 17 Regent Park Square, Glasgow.
741. J. S. Davidson, Sirocco Engineering Works, Belfast.
1895. S. C. Davidson, Sirocco Engineering Works, Belfast.
1230. James Davie, 92 Albert Drive, Crosshill.
2185. C. M. Davies, Leslie House, Pollokshields, Glasgow.

2100. H. Davies, 1 Longcross Street, Cardiff.
192. J. C. Davies, Wood Green, Wednesbury.
1086. L. G. Davies, H.M. Dockyard, Portsmouth.
2321. Thos. A. Davies, Trelawne, Rinswell Hill, London,
1371. W. H. Davies, St. Aubyns, Newport, Mon.
2367. A. T. Davis, County Surveyor, Shrewsbury.
+ 487. J. Davis, Gas Works, Gravesend, Kent.
472. T. Davis, 20 Alexandra Road, Southampton.
504. R. C. H. Davison, 25 Victoria Street, Westminster, London, S.W.
208. Capt. Cecil Wm. Davy, 10 Portland Avenue, Exmouth.
1204. R. A. Dawbarn, 82 Victoria St., London, S.W.
964. John N. Dawe, Wadebridge, Cornwall.
972. Edw. Dawson, 23 Park Place, Cardiff.
1604. Robt. Dawson, Hartley Works, Stalybridge.
326. Wm. Dawson, Town Hall, Leyton, London, E.
1390. G. St. John Day, Mumps Electrical Works, Albert Street, Oldham.
1894. W. O. Dayson,, Blaenavon Works, Blaenavon, Mon.
+ 57. M. Deacon, Whittington House, Nr. Chesterfield.
2280. Harold Deans, 14 Culmington Road, Ealing.
1294. Robert L. Deans, Hillcrest, Johnstone.
1441. Jas. Deas, Water Engineer, Warrington.
1763. M. de Borhek, Commission Européenne du Danube, Galatz, Roumania.
287. Jules de Coene, 26 Rue Etoupee, Rouen, France.
168. E. T. d'Eyncourt, Fairfield, Govan.
288. Henri de Gorski, 8 Quai Cockerill, Seraing, Belgium.
1798. E. F. de Hoerschelmann, Councillor of State, Kieff, Russia.
724. Wm. Deighton, 1 Ash Hall Lane, Chapeltown Road, Leeds.
258. G. de Joly,, 43 Avenue du Trocadero, Paris.
2374. Adolpho F. de Laureiro, 88 Ruadas Janellas Verdes, Lisbon.
991. Carl Dellwik, 25 Victoria St., Westminster, London, S.W.
1813. M. de Loehr, Commission Européenne du Danube, Galatz, Roumania.
1912. Julio de Luzurtegui, Alameda de Mararredo, Y.Y., Bilbao.
1817. His Excellency Don Arturo de Marcoartu, Hotel d'Angleterre, Bilbao, Spain.
878. Emile Demenge, 89 Avenue de Villiers, Paris.
869. J. Dempster, 571 Shields Road, Glasgow.
++ 421. R. Dempster, Norwood, Broughton Park, Manchester.
2063. Archd. Denny, Braehead, Dumbarton.
1896. T. J. Denny, Blast Furnace Power Syndicate, Ltd., 29 Gt. George Street, Westminster, London, S.W.
59. A. de Preaudeau, 21 Rue St. Guillaume, Paris.
544. W. H. de Ritter, 7 Oriental Street, Poplar, London.
1681. G. S. de Rosenkrantz, The South Wales Institute of Engineers, Park Place, Cardiff.
1083. Chas. H. de Rusett, Hope Lodge, Blackheath Hill, S.E.
409. E. W. de Rusett, Warden House, Tynemouth, Northumberland.
1846. M. F. de Schryver, Ingenieur en Chef, Rue de Canal 47, Brussels.
1366. E. C. de Segundo, 28 Victoria Street, London, S.W.
2373. J. M. Cordeiro de Sousa, 45 Rue de Don Pedro V., Lisbon, Portugal.
300 James Dewhirst, Avenue Chambers, Chelmsford, Essex.
232. F. W. Dick, Easthill, Rotherham.
311. John R. Dick, The Reason Manufacturing Co., Ltd., Lewes Road, Brighton.
1192. Jas. B. Dickie, "Sorrento," Terregles Avenue, Pollokshields.
306. Harold Dickinson, 1 Whitevale Road, Leeds.
305 Samuel Dickinson, Wilton Lodge, Wolverhampton.
923. W. J. Dilley, 8 Granby Road, Edinburgh.

1734. J. T. T. Dillon, R.E. Office, Armagh, Ireland.
213. Charles F. Dixon, Cleveland Bridge Work, Darlington.
176. Edward Dixon, 74 Bartholomew Road, Camden Rd., London, N.W.
563. E. W. Dixon, 14 Albert Street, Harrogate.
303. Frederic J. Dixon, 5 Prospect Crescent, Harrogate.
++ 81. James S. Dixon, Fairleigh, Bothwell.
1499. J. R. Dixon, 4 St. Nicholas Buildings, Newcastle-on-Tyne.
++ 1388. Walter Dixon, 59 Bath Street, Glasgow.
520. Joseph Dobbs, Coolbawn, Castlecomer, Co. Kilkenny.
++ 982. Thos. J. Dodd, East Villa, 16 Leslie Rd., Pollokshields, Glasgow.
1030. E. E. Doddrell, 11 Bothwell Street, Glasgow.
401. A. Dodgeon, Urban District Council, Clayton-le-Moors, Accrington.
459. T. E. Dodgson, Granby House, Park Site, Rotherham.
529. E. R. Dolby, 21 Henderson Rd., Wandsworth Common, London, S.W.
632. D. B. Donald, Roseleigh, Penryn, Cornwall.
2104. David P. Donald, Greenbank, Johnstone.
159. James A. Donald, 12 Waterloo Street, Glasgow.
2266. R. H. Dorman, County Surveyor, Armagh.
58. C. P. Douglas, Thornbeck Hill, Darlington.
837. C. S. Douglas, St. Brides, Dalziel Drive, Pollokshields, Glasgow.
942. M. Douglas, Usworth Hall, Washington, R.S.O., Co. Durham.
1897. W. L. Douglas, 8 Clydesdale Street, Hamilton.
1507. A. M. Downie, 51 Cecil Street, Hillhead, Glasgow.
1303. Nicholas Downing, Glenbrooke, Norton Hill, Stockton-on-Tees.
937. E. A. Dowson, Basingstoke Iron Works, Basingstoke, Hants.
1735. John A. Drake, Thornleigh, Halifax.
161. Alexandre Dreux, Mont St. Martin (Meurthe & Moselle), France.
562. W. N. Drew, Ecclesfield, Nr. Sheffield.
807. R. W. Dron, Utica, Bearsden, Glasgow.
320. Wm. Dronsfield, Brookhurst, Oldham.
2363. A. G. Drury, C.R. Docks, Grangemouth.
1444. C. D. Drury, Hendon Gas Works, Sunderland.
2137. Chas. Vickery Drysdale, Clairville, Hadley Rd., New Barnet, London.
390. John W. W. Drysdale, 37 Westercraigs, Dennistoun, Glasgow.
1157. Wm. Duddell, 47 Hans Place, Chelsea, London, S.W.
96. Peter Duff, Dock Engine Works, Birkenhead.
244. W. Duff, 9 Market Street. Morecambe.
417. W. H. Dugard, Bridge Street West, Birmingham.
1471. W. M. Duguid, Blackdog Farm, Bridge of Don, Aberdeen.
548. M. Dumur, Ingenieur des Ponts et Chaussees, Torcalquier, (Bases Alpes), France.
698. John Duncan, Municipal Technical Institute, West Ham, London.
++ 1220. John Duncan, Ardenclutha, Port Glasgow.
++ 2061. Robert Duncan, Whitefield Engine Works, Govan.
2162. Robt. Duncan, c/o Chas. E. Raeburn, 1 Hillhead Street, Glasgow.
1710. William L. Duncan, Lamorna, Scotstounhill, Renfrewshire.
800. G. R. Dunell, 7 Spencer Road, Chiswick, London, N.
1511. Ernest C. Dunkerton, Globe Works, Lincoln.
1246. Alex. Dunlop, 14 Derby Terrace, Sandyford.
++ 1557. David J. Dunlop, 198 Bath Street, Glasgow.
1618. D. N. Dunlop, Westinghouse Building, Norfolk Street, Strand, London, W.C.
++ 2227. John G. Dunlop, Clydebank Shipyard, Glasgow.
1137. Thos. Dunlop, 156 Hyndland Road, Glasgow.
1587. W. A. Dunlop, Harbour Office, Belfast.
2010. Andrew S. Dunn, 1 Thornville Ter., Wilson St., Hillhead, Glasgow.
1376. Hugh S. Dunn, Earlston Villa, Caprington, Kilmarnock.
+ 257. J. Dunn, 28 Victoria Street, London, S.W.

2359. Matt. Dunn, Gas Works Engineer, Goule.
1542. Robt. A. Dunn, 168 Kenmure Street, Pollokshields, Glasgow.
132. Walter T. Dunn, 47 Fentiman Road, London, S.W.
++1736. James Dunnachie, Glenboig House, Glenboig.
167. Henry Dyer, 8 Highburgh Terrace, Dowanhill.

E

1899. W. Frank Eagland, "The Iron and Coal Trades Review," 165 Strand, London, W.C.
1506. W. L. Eaglesfield, Craig House, Workington.
1156. H. A. Earle, Salford Iron Works, Manchester.
1605. J. M. Easton, Tordarroch, Helensburgh.
873. W. C. Easton, Glasgow Main Drainage Works, Balshagray Avenue, Partick.
1119. J. T. W. Echevarrie, 6 Manor Villas, Norfolk Road, Merton, Surrey.
862. E. M. Eden, 76 Adelaide Road, South Hampstead, London, N.W.
2205. Alfred Edington, New Street, Chelmsford.
360. James B. Edmiston, The Cottage, Highfield Rd., Walton, Liverpool.
1586. Alfred R. Edmondson, The Oaks, Moss Lane, Timperley, Cheshire.
1247. Charles Edwards, 36 Hamilton Park Terrace, Hillhead.
1473. E. R. Edwards, Rose Cottage, Crabtree, Pitsmoor, Sheffield.
1777. Azarian Effendi, Commission European du Danube, Galatz.
++ 38. Francis Elgar, Doonbrae, Ayr.
+1454. Professor A. C. Elliott, University College, Cardiff.
1085. Wm. R. Elliot, 12 Albany Gardens, Shettleston.
361. Basil Ellis, Oxshotte, Surrey.
1159. E. Ellis, Gt. Northern Railway, Leeds.
802. W. H. M. Ellis, Monktown, Dublin.
1350. J. Ellison, Rose Hill, Harrington, Cumberland.
+ 16. Edward R. S. Escott, 16 Clifton Road, Halifax.
17. W. B. Esson, Victoria Works, Charlton, Kent.
455. P. T. J. Estler, Fairfield House, Old Charlton, London, S.E.
1502. John Etherington, Spring Mount, 201 Grove Lane, Denmark Hill, London, S.E.
1370. John Eustice, 26 Wilton Avenue, Southampton.
528. A. J. L. Evans, Town Hall, Luton, Beds.
990. C. J. Evans, 108 Castlenan, Barnes, London, S.W.
1778. C. Evans, Pen-yr-Hoel House, Merthyr Tydvil.
116. D. Evans, Carlton Villa, Oxford Street, Upperthorpe, Sheffield.
2365. Evan Evans, County Surveyor, Carnarvon.
1900. G. W. Evans, Westfa, Nr. Llanelly, Carmarthenshire.
1991. John Evans, Cyfartha Iron and Steel Works, Merthyt Tydvil.
+ 97. Thos. Evens, 3 Crescent Road, South Norwood, London, S.E.
2094. Wilfred H. Everett, 215 Woodborough Road, Nottingham.
1898. P. Ewen, The Barrowfield Iron Works, Ltd., Fordneuk Street, Mile End, Glasgow.

F

2234. E. Fabri, Inspector of Factories, Ghent, Belgium.
339. Edgar H. Fairgrieve, 40 Marchmont Crescent, Edinburgh.
476. M. M. Fairgrieve, 6 Burgess Terrace, Edinburgh.
133. G. W. Fairles, Bank House, Upper Parlestone, Dorset.
1589. John Fairley, 124 Pitt Street, Glasgow.
++1431. W. H. Farnell, Gallowflat, Rutherglen.

1901. Ernest Farnworth, Broadlands, Goldthorn Hill, Wolverhampton.
448. Wm. Farrar, 72 Steade Road, Sheffield.
947. R. C. Farrell, 70 Wellington Street, Glasgow.
2242. Alex. Faut, 120 Holland Street, Glasgow.
332. F. H. Faviell, 45 Leadenhall Street, London, E.C.
1779. R. Feldtmann, 104 West George Street, Glasgow.
279 E. A. Fella, 68 Messina Avenue, West Hampstead, London.
266. E. G. Ferber, Claremont, Fernhill Road, Bootle, Liverpool.
811. D. Ferguson, Glenholm, Port-Glasgow.
880. John Ferguson, 12 Broomhill Avenue, Partick.
2229. Peter Ferguson, 19 Exchange Square, Glasgow.
1141. C. Fernau, Nenthead House, Alston, Cumberland.
505. Wm. Fiddian, Elmhurst, Stourbridge.
++ 1363. M. B. Field, 94 Hyndland Road, Kelvinside, Glasgow.
1902. John Fielding, Atlas Ironworks, Gloucester.
1087. Alex. Findlay, Bellfield, Motherwell.
891. C. Finlayson, Laird Street, Coatbridge.
1578. F. Finlayson, Laird Street, Coatbridge.
1781. Ambrose Firth, The Brightside Foundry and Engineering Co., Ltd Sheffield.
1737. W. Firth, 13 Burton Crescent, Headingley, Leeds.
610. Alex. Fisher, 10 Craigie Terrace, Ferry Road, Dundee.
+ 685. Prof. M. F. FitzGerald, 32 Eglantine Avenue, Belfast.
1780. Stanley G. Flagg, jun., 420 North 19th Street, Philadelphia, U.S.A.
646. David Flather, Standard Steel Works, Sheffield.
2222. Geo. E. Fleming, 163 St. Vincent Street, Glasgow.
712. M. J. Fleming, Mount View, John's Hill, Waterford, Ireland.
2207. Thos. J. Fleming, 25 Victoria Street, London, S.W.
2330. James Fletcher.
1561. George Flett, 110 Cannon Street, London, E.C.
2247. Dr. Walther Fliby, 109 Victoria Street, London, S.W.
938. M. Fligg, Gas Works, Redcar.
1782. Henry Flint, Machine and Colliery Stores Merchant, Ince, Wigan.
1783. J. Fontes, Toulouse, France.
1784. Harry Footner, L.N.W.R., Permanent Way Dept., Engineer's Office, Crewe.
1330. Prof. Geo. Forbes, 34 Great George St., Westminster, London, S.W.
522. Chas. F. Ford, St. John's Villa, Ripley, Nr. Derby.
1245. Edward L. Ford, Iron & Steel Institute, 28 Victoria St., London, S.W.
1082. T. W. Ford, Palace Chambers, Westminster, London, S.W.
++ 190. James T. Forgie, Viewfield, Bothwell.
1531. Alfred L. Forster, 5 Haldane Terrace, Newcastle-on-Tyne.
1191. Lawson Forsyth, Helenslea, Broomfield Road, Springburn, Glasgow.
1677. Foster, Gordon Street, Darlaston.
1053. Edgar Foster, Houseley Villas, Chapeltown, Nr. Sheffield.
1052. Harold T. Foster, Housley Villas, Chapeltown, Nr. Sheffield.
1738. John A. Foster, Ladywalk, Rickmansworth, Herts.
319. Martin Foster, Claremont, Norton Road, Stockton-on-Tees.
2193. W. Foster, 230 Duke Street, Barrow-in-Furness.
++ 1555. Wm. Foulis, 45 John Street, Glasgow.
+ 1374. A. M. Fowler, 35 Old Queen Street, Westminster, London, S.W.
1785. W. H. Fowler, 53 New Bailey Street, Manchester.
408. H. Fownes, 6 Osborne Road, Newcastle-on-Tyne.
2254. Chas. B. Fox, Alyn Bank, Wimbledon.
+ 60. Sir Douglas Fox, 28 Victoria Street, Westminster, London, S.W.
270. F. Douglas Fox, 19 Kensington Square, London, W.
39. William Fox, 5 Victoria Street, Westminster, London, S.W.
1583. Samuel Frances, Forton Bank, Hindley, Nr. Wigan.

539. Joseph Francis, Bemersyde, Coolhurst Road, Shepherd's Hill, London, N.
579. W. A. Francken, Okehampton, Devon.
1432. James Fraser, 100 Castle Street, Inverness.
1440. J. I. Fraser, 13 Sandyford Place, Glasgow.
1992. P. A. Fraser, Knockrobbie, Beauly.
1098. P. Fraser, 11 Dalhousie Place, Arbroath.
289. Wm. Fraser, 121 N. Montrose Street, Glasgow.
134. W. J. F. Freeland, c/o Crompton & Co., Arc Works, Chelmsford.
1144. W. W. Freeman, Cheetham Villa, Taylor Street, Dresden, Stoke-on-Trent.
1903. W. E. Freir, 16 Eldon Street, London, E.C.
867. Jas. W. French, 1 Kelvinside Terrace, Glasgow.
2140. P. R. Friedlaender, 39 London Road, Chelmsford, Essex.
2161. Wm. E. Frier, 16 Eldon Street, London, E.C.
314. G. S. Frith, Gas Works, Frodsham, via Warrington.
++ 1786. Alex. Fullerton, Vulcan Works, Paisley.
2231. Charles W. Fulton, The Glen, Paisley.
1001. N. O. Fulton, Woodbank, Mount Vernon.
1297. T. C. Fulton, 44 West George Street, Glasgow.
++ 2064. Peter Fyfe, 23 Montrose Street, Glasgow.

G

474. Enrique Gadea, San Juan 58, Madrid, Spain.
1153. R. L. Gaine, 13 Craigmore Terrace, Dowanhill, Glasgow.
+ 2065. J. M. Gale, City Chambers, Glasgow.
2128. William M. Gale, 18 Huntly Gardens, Kelvinside, Glasgow.
672. A. Galloway, 12 Camphill Avenue, Langside.
++ 468. T. L. Galloway, 43 Mair Street, Glasgow.
1236. T. Galston, 141 Rosebery Place, Tollcross.
814. E. T. Gardiner, South View, Bishop Auckland.
2211. John L. F. Gardner, 15 Waverley Gardens, Glasgow.
2341. Joseph Garfeld, 7 Atsby Villas, Bradford.
1340. D. E. Garlick, Urban District Council, Barnoldswick.
1512. Sydney H. Garnett, 2 Saltoun Gardens, Kelvinside, Glasgow.
++ 1606. Geo. Garrett, Waverley Iron and Steel Works, Coatbridge.
740. H. A. Garrett, Borough and Harbour Engineer, Torquay, Devon.
1286. Wm. Garven, 26 Derby Crescent, Kelvinside.
940. L. C. Gash, Inglecroft House, Hamilton Road, Lincoln.
308. P. T. Gask, 2 Bath Terrace, Seaham Harbour, Co. Durham
1407. L. Gaster, 37 Maida Vale, London, W.
509. T. E. Gatehouse, 4 Ludgate Hill, London, E.C.
98. C. P. Gates, Richmond Villa, Whitegate Drive, Blackpool.
1787. Richard Gaunt, Albany Villa, Eaglescliffe, R.S.O.
585. C. Geddes, Laurel Bank, Huyton Park. Huyton.
1114. N. G. Gedye, 15 Victoria Street, Westminster, London, S.W.
441. Wm. Geipel, 97 Shooters Hill Road, Blackheath, London, S.E.
1584. E. W. Gemmell, Board of Trade Office, 7 York Street, Glasgow.
250. D. George, 20 New Steine, Brighton.
1789. Walter H. German (of Sydney), c/o Messrs. Parbury, Henty & Co., 20 Eastcheap, London, E.C.
1592. John Gerrard, Worsley, Manchester.
907. Alex. Gibb, Contractor's Office, Kew, Surrey.
1905. Jas. Gibson, Phoenix Iron Works, Coatbridge.
354. Ralph E. Gibson, Gas Works, Huddersfield.
1788. H. Gielgud, 140 Leadenhall Street, London.

693. Paterson Gifford, 2 Woodrow Circus, Pollokshields.
236. F. W. Gilbertson, Glyn Teg, Ponterdawe, R.S.O., Glamorgan.
++ 205. James Gilchrist, Stobcross Engine Works, Glasgow.
753. Jas. Gilchrist, Clifton Lodge, Workington.
466. G. F. L. Giles, Harbour Office, Belfast.
9. Henry A. Giles, 11 Victoria Street, London, S.W.
471. John C. Gill, City Electrical Engineer, Peterborough.
366. A. Gillespie, Greenhaugh, Helensburgh.
1266. James Gillespie, jun., Margaretville, Orchard Street, Motherwell.
2176. M. M'A. Gillespie, Westinghouse Building, Norfolk St., Strand, London.
1021. Jas Gillies, 14 Walmer Terrace, Paisley Road, Glasgow.
652. Eugene M. Y. Gillon, 53 Price Street, Hebburn-on-Tyne.
1364. John H. Gilmour, River Bank, Irvine.
556. Hugh Girvan, Daligan, Bearsden.
729. E. C. Given, 1 Aigburth Vale, Liverpool.
++ 2066. The Rt. Hon. The Earl of Glasgow, Kelburne, Fairlie.
386. S. N. Glass, 16 Ravenscroft Road, Chiswick, London.
1487. D. Corse Glen, 3 Lombard Street, London, E.C.
1790. Geo. Glen, Ivor Villa, Newport, Mon.
+ 718. E. Glover, 19 Prince Patrick Terrace, North Circular Rd., Dublin.
1438. Samuel Glover, Hill Crest, North Road, St. Helens, Lancs.
1524. Thomas Glover, Shirley, West Bromwich.
2043. J. F. Golding, Expanded Metal Co., Ltd., 39 Upper Thames St., London, E.C.
302. Wm. S. Gollidge, 41 Queen's Road, Finsbury Park, London.
890. J. P. de Souza Gomes, Largo da Bibliothica 20, Lisbon, Portugal.
+ 304. Prof. John Goodman, The Yorkshire College, Leeds.
884. W. P. Goodrich, 66 Victoria Street, Westminster, London, S.W.
1791. Herbert Goodyear, Borough Engineer, Colchester.
827. J. Gordon, Assistant Burgh Surveyor, Town House, Aberdeen.
2177. E. T. Goslin, 31 Wilson Street, Hillhead, Glasgow.
537. Edward L. Gosset, Watlington, Oxon.
1464. And. H. Goudie, 27 Miller Place, Stirling.
708. A. B. Gowan, 27 South Hamilton Street, Kilmarnock.
++ 1739. Alex. Gracie, Clydeview House, Partick.
2133. Walter Grafton, 102 Byron Avenue, East Ham, Essex.
1433. John Graham, 15 Armadale Street, Dennistoun, Glasgow.
169. The Marquis of Graham, Buchanan Castle, Drymen.
2002. Maurice Graham, Graham, Morton & Co., Ltd., Leeds.
1219. W. Graham, Westwood, Bearsden.
227. F. T. Grant, Borough Surveyor, Gravesend.
156. Thos. F. Grant, 58 Kelvingrove Street, Glasgow.
1904. T. M. Grant, 322 St. Vincent Street, Glasgow.
1792. H. G. Graves, 5 Robert Street, Adelphi, London, W.C.
++ 2360. Prof. Andrew Gray, The University, Glasgow.
1634. Bruce M'G. Gray, Town Hall, Selby.
581. G. W. Gray, 8 Inner Temple, Liverpool.
1793. James Gray, Riverside, Old Cumnock.
+ 2237. R. K. Gray, Lessness Park, Abbey Wood, Kent.
485. A. W. Grazebrook, Queen's Cross, Dudley, Worcester.
443. John Green, London Zinc Mills, Ltd., Wenlock Road, London, N.
670. J. Singleton Green, Borough Surveyor, Haslingden.
1566. William Green, North View Cottage, Beancroft Rd., Castleford, Yorks.
2312. Arthur Greenwood, Messrs. Greenwood & Batley, Leeds.
848. J. Gregory, Upper Chorlton Road, Manchester.
1672. James Gregory, 3 Park Lane, Abram, Nr. Wigan, Lancs.
658. B. W. P. Greig, 17 Osborne Place, Aberdeen, N.B.

587. P. R. Gresham, 51 Howarth Street, Old Trafford, Manchester.
Jordanhill.
1088. John Grieve, Crawford Street, Motherwell.
1331. Joseph Griffin, Victoria Works, Cradley Heath.
++1684. A. Griffiths, The Bonnybridge Silica & Fireclay Co., Bonnybridge.
1272. Harold Griffiths, Thornbury, Woodbourne Road, Edgbaston.
194. William J. Griffiths, 61 Sinclair Road, London, W.
2209. S. Slater Grimley, Hendon, London.
135. F. G. Grimshaw, 364 Van Houten Street, Paterson, N.J., U.S.A.
502. R. A. Groom, Wellington, Salop.
1006. L. J. Groves, Ardrishaig, N.B.
1484. J. Grundel, Hugo de Grootstraat 84, The Hague, Holland.
2228. T. J. Guilbert, Surveyor, Guernsey.
263. A. Guild, Jun., 30 Elmfield Avenue, Aberdeen.
1185. Thos. A. Guyatt, Gas Works, Ely, Cambridge.
1740. Thos. Gwynne, Gwalia Works, Briton Ferry.

H

976. M. H. Habershon, 26 Newbould Lane, Sheffield.
1688. F. Hachez, 19 Rue de Pavie, Bruxelles.
177. R. H. Haggie, Jun., Hylton, Johnstone.
499. Charles Hall, 542 Edge Lane, Droylsden, Near Manchester.
310. Charles J. Hall, 207 Hyde Park Road, Leeds.
100. John Hall, Waterloo, Bury, Lancashire.
467. J. Hall, 138 Market Street, St. Andrews, Fife.
101. John W. Hall, 71 Temple Row, Birmingham.
341. Robert Hall, Castlelea, St. Andrews, N.B.
1430. Thos. A. Hall, Bellevue, Buncrana, Co. Donegal.
710. T. B. Hall, 119 Colmore Row, Birmingham.
1494. W. Silver Hall, Cranethorpe, Guy's Cliff Road, Leamington, Eng.
1155. E. Hall-Brown, 14 Hyndland Road, Glasgow, W.
1404. Geo. Halliday, 148 St. Paul's Road, Canonbury, London, W.
237. Druitt Halpin, 17 Victoria Street, Westminster, London, S.W.
1237. F. Sison Ham, 16 Leopold Road, Wimbledon, London, S.W.
1572. Andrew Hamilton, 124 Shiel Road, Liverpool.
2105. A. Hamilton, Dimsdale, 8 Matilda Road, Pollokshields, Glasgow.
1598. David C. Hamilton, Clyde Shipping Co., Ltd., 21 Carlton Place.
++1552. James Hamilton, 208 St. Vincent Street, Glasgow.
++2136. James Hamilton, Ardedynn, Kelvinside, Glasgow.
2302. Jas. Hamilton, c/o Peterkin, 15 Iona Place, Mount Florida.
875. Jas. Hamilton, 6 Kyle Park, Uddingston.
1658. John Hamilton, 22 Athole Gardens, Glasgow.
1362. John K. Hamilton, 21 Derby Crescent, Kelvinside, Glasgow.
570. Patrick Hamilton, 66 Victoria Street, London, S.W.
+1262. Robert Hammond, 64 Victoria Street, Westminster, London, S.W.
860. R. S. Hampson, Oakwood, Norwood Road, Pitsmoor, Sheffield.
438. A. S. Hampton, 25 Killermont Street, Glasgow.
1447. J. J. Hanbury, Edgeley, Walm Lane, Cricklewood, London, N.W.
851. H. Hand, 342 Argyle Street, Glasgow.
1597. T. Hands, Gas Works, Enniskillen.
1422. A. C. Hanson, 4 Windsor Place, Stirling.
1412. W. Hanson, Failreigh, Norton, Stockton-on-Tees.
136. F. W. Harbord, Coopers Hill College, Englefield Green, Surrey.
102. Alfred E. Hardaker, Engineers' Office, L. & Y. Railway, Hunts Bank, Manchester.

1680. Edward P. Hardie, The London & Scottish Boiler Insce. Co., 128a Queen Victoria Street, London, E.C.
18. J. R. Harding, Dixton Cottage, near Monmouth.
919. Wm. H. Hardy, Jansey Green, Pinsneth, Nr. Dudley.
1143. W. Hardy, St. Oswalds, Alexandra Road, Upper Norwood.
2210. H. J. B. Hargrave, 56 Upper Mount Street, Dublin.
720. J. H. Hargrave, 4 Haddington Terrace, Kingstown, Co. Dublin.
580. B. S. Harlow, Ardgowan, Spencer Road, Buxton.
801. Bruce Harman, 35 Connaught Road, Harlesden, London, N.W.
+ 61. W. Harpur, Town Hall, Cardiff.
344. Wilfred M. Harris, Endcliff, Kendal.
929. J. E. Harrison, 160 Hope Street, Glasgow.
2118. J. Fred Harrison, 9 Beechwood Drive, Jordanhill, Glasgow.
+ 40. J. H. Harrison, 2 Exchange Place, Middlesbro'-on-Tees
2274. J. A. Harrop, Moss, Wrexham.
1273. John Hart, 5 Meson Terrace, Middlesborough.
1287. P. C. Hart, Monkbarns, Prestwick, Ayrshire.
1279. John W. Hartley, Drysdale House, Stone, Staff.
183. John H. Harvey, Benclutha, Port-Glasgow.
365. W. B. Harvey, 7 Marchmont Terrace, Kelvinside.
984. Arthur Hassam, Madeley, Staffordshire.
++ 834. Jas. Hastie, Greenfield, Burnbank, Lanarkshire.
706. Wm. Hastie, 78 Finnart Street, Greenock.
117. George Hatton, Round Oak Works, Brierley Hill.
999. Wm. Hawdon, c/o Messrs. Sir B. Samuelson & Co., Middlesborough.
596. Walter Hawkings, 24 Denbigh Road, Bayswater, London, W.
+ 235. Charles Hawksley, 30 Gt. George Street, Westminster, London, S.W.
1794. G. W. Hawksley, Saville Street, Sheffield.
617. K. P. Hawksley, 30 Great George Street, Westminster, London, S.W.
1795. W. R. Hay, 20 Abchurch Lane, London, E.C.
756. T. A. Hayward, 18 Carrington Street, Glasgow.
368. A. P. Head, 47 Victoria Street, London, S.W.
584. B. W. Head, 47 Victoria Street, Westminster, London, S.W.
1560. David Heap, 110 Cannon Street, London, E.C.
541. Douglas T. Heap, 21 Lea Park, Blackheath, Kent.
252. W. Heap, 29 Botanic Avenue, Belfast.
2283. T. A. Hearson, 8 Glenhouse Road, Blackheath, London.
99. Captain T. B. Heathorn, 10 Wilton Place, Knightsbridge, London.
41. C. Heaton, Brades Steel Works, Nr. Birmingham.
519. Robert Hedley, Weardale House, Spennymoor.
2353. Augustus Helder, M.P., Whitehaven.
1339. Geo. Helps, Gas. Works, Nuneaton.
+ 1703. James W. Helps, Gas Works, Croydon.
1213. H. Henderson, 27 Cowper Street, Leeds.
1186. J. Henderson, Frodingham Iron Works, Nr. Doncaster.
1145. W. D. Helps, Cherry Bank, Kirkstall, Leeds.
818. James Henderson, Frodingham House, Frodingham, Nr. Doncaster.
854. Jas. B. Henderson, 146 Cambridge Drive, Glasgow.
1448. J. F. Henderson, 4 Belhaven Crescent, Kelvinside.
1062. J. G. Henderson, Inst. of Civ. Engrs., Gt. George St., London, S.W.
2354. Robert Henderson, Harbour Engineer, Burntisland.
340. Sir William Henderson, LL.D., Devanha House, Aberdeen.
1101. Thos. Hennell, 6 Delahay Street, London, S.W.
1908. Gus. C. Henning, 220 Broadway, New York, U.S.A.
410. W. H. Hepplewhite, Blenheim Mount, St. Ann's Hill, Nottingham.
+ 816. J. Hepworth, 4 Priestfield Road, Edinburgh.
475. H. Hermann, Munster, i/w, Germany.
++ 2067. W. R. Herring, Granton House, Edinburgh.

965. Geo. Herriot, 24 Moray Place, Strathbungo.
956. A. Herschel, 2 Glenavon Terrace, Crow Road, Partick.
2301. Thos. Hewson, The Hollies, Roundhay, Leeds.
2216. Dr. Adolphus Heyck, Budapest, Hungary.
230. John Hibbard, Greenside House, Hackenthorpe, Sheffield.
518. Wm. S. Hide, Beechwood, Cottingham, E. York.
2214. Charles F. Higgins, Moore Parade, Hartlepool.
636. Arthur Higgs, Batman's Hill, Bradley, Bilston.
1504. David G. Hill, 70 Marchmont Road, Edinburgh.
2114. Edward J. Hill, 11 Victoria Street, Westminster, London.
2035. W. H. Hill, jun., Audley House, Cork.
1796. William Hill, Apedale, Newcastle, Staffs.
1048. Maurice Hird, 46 Maryon Road, Charlton, Kent.
206. W. Benison Hird, 13 Albion Crescent, Glasgow.
19. D. J. Hirst, 33 Hartington Street, Barrow-in-Furness.
++ 2068. G. R. Hislop, Gas Works, Paisley.
469. Lawrence Hislop, Gas Works, Uddingston.
1742. Chas. F. Hitchens, 25 Victoria Street, Westminster, London, S.W.
275. H. M. Hobart, 123a Potsdamerstrasse, Berlin.
1391. G. M. Hocknell, 47 Somerset Road, Huddersfield.
++ 1797. John Hodgart, Vulcan Works, Paisley.
1607. Geo. Hodgkinson, 9 Throgmorton Avenue, London, E.C.
1039. H. E. Hodgson, Spen Hall, Cleckheaton.
1574. Henry T. Hodgson, Harpenden, Herts.
1909. Stephen Hodgson, 76 Scarbro' Street, W. Hartlepool.
++ 2096. Hugh Hogarth, Dock Shipbuilding Yard, Port Glasgow.
2097. S. C. Hogarth, Dock Shipbuilding Yard, Port Glasgow.
709. T. O. Hogarth, The Woodlands, Swindon.
1009. W. A. Hogarth, 293 Onslow Drive, Glasgow.
++ 1024. C. P. Hogg, 53 Bothwell Street, Glasgow.
137. William Hogg, Piele House, Beach Street, Lytham, Lancs.
211. John Hojer, Lotsstyrelsen, Stockholm.
1582. Alfred Holden, Hindley, Nr. Wigan.
1113. Col. Holden, R.A., Royal Arsenal, Woolwich.
445. T. E. Holgate, 173 Hollins Grove, Darwen.
2014. Thos. Holgate, Gasworks, Halifax.
1969. Roslyn Holiday, Ashton Hall Colliery, Featherstone, Pontefract.
512. E. M. Hollingsworth, Prescot Road, St. Helens, Lanc.
++ 952. H. E. Hollis, 40 Union Street, Glasgow.
1269. F. G. Holmes, Town Hall, Govan.
2084. G. C. V. Holmes, Office of Public Works, Dublin.
1379. J. H. Holmes, Wellburn, Jesmond, Newcastle-on-Tyne.
2121. Matt. Holmes, Netherby, Lenzie.
852. Carl Holmstrom, Lancefield Engine Works, Glasgow.
589. W. M. Homan, 10 Rosslyn Terrace, Kelvinside.
887. J. J. Hopper, Wire Rope Works, Thornaby-on-Tees.
498. John Horan, 82 George Street, Limerick.
2324. H. Horne, 31 Cecil Street, Hillhead, Glasgow.
796. W. Horner, 2 Vancouver Road, Catford, S.E.
1910. H. K. L. Hornfall, Penns Hall, Erdington, Warwickshire.
1799. Arthur Horsefield, High Bank, Horbury, Nr. Wakefield.
717. R. Horsfield, Alvanley House, Bredbury, Nr. Stockport.
745. S. S. Horsfield, Beech House, Blaenavon, Mon.
1384. E. Horton, The Grange, Bescot, Walsall, Staffs.
2131. William Hossack, Wood Merchant, Orton.
2316. John Houlding, Stanley House, Oakfield Road, Liverpool.
1003. C. Houston, 39 Melville Street, Pollokshields.
1463. J. R. Howard, Parkside Place, Johnstone, N.B.
415. F. Howarth, Municipal Buildings, Plymouth.

2102. W. Howat, Elliot Street, Cranstonhill.
++1007. Jas. Howden, 2 Princes Terrace, Glasgow.
1800. S. Earnshaw Howell, Brook Steel Works, Sheffield.
637. W. T. Howse, Bexleyheath, Kent.
1801. James Rossiter Hoyle, Norfolk Works, Sheffield.
1434. P. S. Hoyte, Mona House, Coxside, Plymouth.
62. Col. H. M. Hozier, Secretary of Lloyd's, London, E.C.
1526. R. S. Hubbard, 3 Crow Road, Partick, Glasgow.
170. John G. Hudson, Glenholme, Brownley Cross, Bolton, Lancs.
2089. Wm. J. Hudson, North Lincoln House, Fordingham, Doncaster.
1907. Wm. Hudspith, Greencroft, Haltwhistle.
484. H. W. Hughes, 188 Wolverhampton Street, Dudley, Worcester.
631. J. G. Hughes, Simddawen, Cemaes, Anglesev.
950. L. H. Hughes, St. Catherines, Hendon, London, N.W.
63. T. Vaughan Hughes, Norwich Union Chambers, Congreve Street, Birmingham.
1008. J. Howden Hume, Haylie, Clarkston, Busby, Nr. Glasgow.
495. Chr. Hummel, 6 Nyvej, Copenhagen V., Denmark.
1458. J. H .Humphreys, Norwood, Cambridge Rd., Bowden, Cheshire.
+ 103. Chas. Hunt, Gas Works, Windsor Street, Birmingham.
491. F. O. Hunt, 43 Lord Street, Broughton, Manchester.
418. G. J. Hunt, Guildhall, Dorchester.
531. L. J. Hunt, Marlborough House, St. Johns Street, Chester.
920. Adam Hunter, 32 Victoria Street, Westminster, S.W.
350. G. Ernest Hunter, Aykleyheads, Durham.
2355. Gilbert M. Hunter, New Yards, Maybole.
1691. John M. Hunter, 42 Montgomerie Street, Kelvinside, Glasgow.
357. John W. Hunter, 10 Princes Street, Sunderland.
++ 804. John Hunter, 13 Queen's Gate, Dowanhill, Glasgow.
918. John Hunter, Dolphin Foundry, Leeds.
603. J. Y. Hunter, Temora, W. Cults, Aberdeen.
1741. Thos. M. Hunter, 31 Lynedoch Street, Glasgow.
618. Tom Hunter, Town Hall, Leigh, Lancashire.
425. W. H. Hunter, Oakhurst, Eccles Old Road, Manchester.
1803. W. Henry Hunter, Engineer's Office, 41 Spring Gardens, Manchester.
2165. Wm. Hunter, Germiston Bolt Works, Petershill Road, Glasgow.
420. A. E. Hurse, 4 Cobham Terrace, Greenhithe, Kent.
178. A. C. Hurtzig, 2 Queen Square Place, Queen Anne's Mansions, Westminster, S.W.
1194. J. Hutcheon, 46 Park Drive South, Whiteinch, Glasgow.
743. Chas. H. Hutchinson, Falcon Works, Sackville Street, Barnsley.
2046. Walter W. Hutchinson, Gas Works, Barnsley, Yorks.
1906. Wm. Hutchinson, Penn House, Wolverhampton.
2036. Daniel L. Hutchison, 3 Spring Gardens, Charing Cross, London.
1282. George L. Hutchison, 9 Park Quadrant, Glasgow.
835. Robert Hutchison, 76 Kenmure Street, Pollokshields, Glasgow.
104. A. W. Hutton, Alma Tube Work, Walsall.
1131. Geo. P. Hyslop, Sidmouth Avenue, Newcastle-under-Lyme, Staffs.

I

897. Geo. Idin, Hopedale, Spencer Park, Coventry, England.
414. Wm. Ingham, Town Hall Chambers, Torquay.
8. Joseph Ingleby, 20 Mount Street, Manchester.
++2069. John Inglis, LL.D., 4 Princes Terrace, Dowanhill.
949. J. Inglis, 49 Mayfield Road, Edinburgh.

1055. S. J. Ingram, Gas Works, Truro, Cornwall.
1170. Wm. Innes, 11 Walmer Terrace, Ibrox, Glasgow.
564. W. A. Ironside, 1 Gresham Buildings, London, E.C.
2109. Daniel Irving, Gas Office, Bristol.

J

697. Alex. Jack, 164 Windmillhill, Motherwell.
1058. A. J. Jackman, Persberg Steel Works, Attercliffe Common, Sheffield.
1057. Joseph Jackman, Persberg Steel Works, Attercliff Common, Sheffield.
1743. J. W. Jackman, c/o C. W. Jackman & Co., Machine Merchants, 39 Victoria Street, London, S. W.
1501. T. W. M. Jacks, Hillside, Squire's Walk, Wednesbury.
1563. Algernon B. Jackson, 16 Gt. Tower Street, London, S.E.
507. A. E. Jackson, City Engineer's Dept., Town Hall, Hull.
++ 2356. Douglas Jackson, Main Street, Newmains.
684. F. Jackson, Victoria Foundry, Cardiff.
1804. G. M. Jackson, The Clay Cross Co., Clay Cross, Nr. Chesterfield.
1411. H. Jackson, Glenthorn, Horwich, Lancashire.
1351. J. Jackson, 3 Hallside, Newton.
993. Peter Jackson, 3 Walmer Crescent, Glasgow.
992. Wm. S. Jackson, 3 Walmer Crescent, Glasgow.
2039. W. Jacobsen, Bergannd, Stockholm.
1744. Wm. Jaffrey, 3 Victoria Street, Westminster, London, S.W.
1641. Enoch James, Ashburton Terrace, Middlesbrough.
789. T. James, 4 Viewforth Terrace, Fulwell, Sunderland.
++ 489. Prof. A. Jamieson, 16 Rosslyn Terrace, Kelvinside, Glasgow.
1200. Wm. Jarvie, c/o Kirk, Main Street, Bothwell.
1806. J. S. Jeans, 165 Strand, London, W.C.
195. Alfred Jenkins, Sunny Bank, Abergavenny.
++ 1809. James G. Jenkins, 33 Renfield Street, Glasgow.
1745. G. Joram Jenkins, 16 Bridge Street, Aberdeen.
1014. Thos. Jenkinson, 17 Windle Street, St. Helens.
1807. H. M. Jenks, Heath Town, Wolverhampton.
1808. Joseph Jenks, Heath Town, Wolverhampton.
138. Walter Jenks, Dunstall, Wolverhampton.
1485. Karl Jenny, Innsbruck, Bahnhof, Tyrol, Austria.
64. Geo. Jessop, London Steam Crane Works, Leicester.
201. Wm. J. Jobling, Norse Villa, Morpeth.
1307. And. Johnson, 120 Nithsdale Road, Glasgow.
1367. L. P. Johnson, 9 Blackheath Rise, Lewisham, London, S.E.
863. David Johnstone, 9 Osborne Terrace, Govan.
394. Geo. Johnstone, 5 Albany Street, Edinbrugh.
1513. Ronald H. Johnstone, 28 Athole Gardens, Glasgow.
20. W. J. Johnston, 13 Victoria Road, Broomhall Park, Sheffield.
171. John T. Joliffe, Warrington Road, Ipswich.
2015. A. Joly, 11 Rue de Printemps, Paris.
2037. Arthur D. Jones, Lostock Junction, Bolton, Lancashire.
324. Lt.-Col. Alfred S. Jones, V.C., Finchampstead, Berks.
1452. E. P. Jones, The House by the Church, Tattenhall, Staffs.
1746. Hy. E. Jones, Gas Works, Stepney, London.
1475. J. Jones, Velindre, Wood Green, Wednesbury, Staffs.
664. James C. Jones (of South Bank), 30 Vansittart Terrace, Redcar.
65. Llewellyn Jones, 98 Great Tower Street, London, E.C.
1666. Thos. C. Jones, 17 Kent Avenue, Jordanhill, Glasgow.
1034. Walter Jones, Holly Mount, Red Hill, Stourbridge.

924. Edw. Josselyn, c/o Messrs. A. Ransome & Co., Ltd., Stanley Works, Newark-on-Trent.
2126. Basil H. Joy, 85 Gracechurch Street, London.
1993. Edwin H. Judd, 1 St. Ronan's Drive, Shawlands.
886. Wm. H. Jukes, Fern Villa, Burnt Tree, Tipton, Staffs.
85. Marius Jullien, Marseilles.

K

21. C. Kadono, c/o Okura & Co., 53 New Broad Street, London, E.C.
996. Tatsuzo Kajima, Tokio, Japan.
649. T. Kazama, 50 South Street, Greenwich.
1395. T. J. M. Keegan, 41 Margaret Street, Greenock.
+ 1396. A. Keen, London Works, Nr. Birmingham.
160. Alex. Kelly, 18 Doune Terrace, Kelvinside.
++ 2122. Lord Kelvin, Netherhall, Largs.
496. A. N. Kemp, 133 Brecknock Rd., St. John's College Park, London N.
1182. Irvine Kempt, jun., Foresthill, Kelvinside, Glasgow.
1308. H. Kendrick, Gas Works, Stretford, Manchester.
870. D. W. Kenmont, Machan Avenue, Larkhall.
1675. Alex. M. Kennedy, Clydevale, Dumbarton.
2295. Captain Kennedy, King's Wood Villas, New Brompton.
2248. Jas. Kennedy, 88 Hyndland Road, Glasgow.
1295. Robert Kennedy, 7 Howard Street, Kilmarnock.
1510. Robt. S. Kennedy, 11 Fellows Road, London, N.W.
++ 2320. Thos. Kennedy, Kilmarnock.
1483. Wm. E. Kenway, 319 Hagley Road, Birmingham.
++ 370. James Kerr, The Knowe, Motherwell.
682. C. S. Kershaw, Penwylt, N. Neath, S. Wales.
1608. William Key, 109 Hope Street, Glasgow.
454. H. G. Keywood, Maldon, Essex.
379. Michael Khroncheffski, Shlusselburg, Russia.
1911. John Kidd, Consett, Co. Durham.
931. M. H. Kilgour, 4 Blenheim Parade, Cheltenham.
182. Peter G. Killick, Finsbury Town Hall, London, E.C.
1135. H. B. Killon, Heaton Moor Road, Nr. Stockport.
721. Jas. Kimber, 59 Canfield Gardens, South Hampstead, London, N.W.
1089. N. Kimura, 5 Park Terrace, Govan.
777. J. G. Kincaid, 30 Forsyth Street, Greenock.
1199. C. A. King, 12 Kew Gardens, Kelvinside. Glasgow.
++ 172. J. Foster King, 121 St. Vincent Street, Glasgow.
439. John King, 165 Victoria Road, Aberdeen.
+ 345. Wm. King, Gas Office, Duke Street, Liverpool.
620. W. King, 11 Bolt Court, Fleet Street, London, E.C.
1488. A. J. Kinghorn, 93 Millbrae Road, Langside, Glasgow.
105. J. G. Kinghorn, Ardoch, Prentin, Oxton, Cheshire.
828. Wm. A. Kinghorn, 81 St. Vincent Street, Glasgow.
629. A. T. Kinsey, Aldborough House, Dublin.
465. O. J. Kirkby, Carlton House, Batley, Yorkshire.
525. Henry Kirk, Seaton Road, Workington.
622. W. G. Kirkaldy, 6 Caleton Road, Tufnell Park, London, N.
118. William Kirkham, 22 Brinsworth Street, Attercliffe, Sheffield.
552. John Kirkland, 23 Angles Road, Streatham, London, S.W.
1558. Ernest C. Knight, 45 Scotland Street, Glasgow.
1038. Geo. S. Knight, jun., 155 Fenchurch Street, London.
2115. H. J. C. Kuhl, 21 Delahay Street, Westminster, London, S.W.

L

++ 367. W. W. Lackie, 14 Doune Terrace, N. Kelvinside.
1385. C. E. Lacy-Hulbert, 45 Rue Henri Maus, Brussels, Belgium.
1708. Robert Laidlaw, 6 Marlborough Terrace, Glasgow.
225. Wm. C. Laidler, 26 Ewesley Road, Sunderland.
1443. And. Laing, 15 Osborne Road, Newcastle-on-Tyne.
614. W. A. B. Laing, 18 Dean Terrace, Edinburgh.
2155. Andrew Laird, 190 West George Street, Glasgow.
1051. Richard Laithwaite, De Trafford House, Ince, Wigan.
++ 1913. And. Lamberton, Sunnyside Engine Works, Coatbridge.
830. W. Lamont, Cairnsmone, Helensburgh.
1410. J. Lancaster, Auchenheath, Lanarkshire.
82. W. Laudell, Craigville, Toward Point, Argyleshire.
1036. C. R. Lang, Morven, Quadrant Road, Newlands, Glasgow.
1693. Robt. Lang, Quarrypark, Johnstone.
784. Wm. Langdon, Percy House, Bath, Somersetshire.
+ 2054. W. E. Langdon, Glenalmond, 15 Cavendish Crescent, The Park, Nottingham.
1516. Ernest F. Lange, Fairholm, Willow Bank, Fallowfield, Manchester.
1325. Wm. Langford, Surrey House, Trentham Road, Longton, Staffs.
1437. S. B. Langlands, Gas Engineer, Coleraine, Co. Derry.
1747. Oskar Lasche, N. Brunnenstrasse 107a, Berlin.
1222. Jas. Lauder, Windsor Place, Bridge-of-Weir.
1914. Thomas H. Lauder, Parkhead Forge, Glasgow.
492. J. H. W. Laverick, Pyr Hill, Jacksdale, Notts.
++ 2070. A. Bonar Law, M.P., 23 Royal Exchange Square, Glasgow.
1415. Henry Lawrence, P.O. Chambers, Newcastle-on-Tyne.
1238. George E. Lawton, Aidenswood House, Kidsgrove, Staffs.
42. Henry Lea, 38 Bennett's Hill, Birmingham.
1218. M. Lea, Kenwyn View, Truro, Cornwall.
508. C. C. Leach, Seghill, Northumberland.
1239. H. L. Leach, 28 Leigham Court Road, W., Streatham, London, S.W.
687. Joel. Lean, Castle Hill, Duffield, Derby.
1514. L. N. Ledingham, Govandale, Elmore Road, Sheffield.
238. Richd. Le Doux, West Derby, Liverpool.
1405. Henry Lee, Bedford Lodge, Broughton Park, Manchester.
574. J. J. Lee, Engineer's Office, L. & N.W. Railway, Stafford.
1020. Walter Lee, 38 Worple Road, Wimbledon, S.W.
351. James Lees, 4 The Terrace, Tonbridge, Kents.
602. A. S. Legat, Carnbroe Cottage, Coatbridge.
1567. E. J. Legg, Town Hall, Christchurch, Hants.
1302. Sir Joseph Leigh, M.P., Nestbourne, St. Annes-on-the-Sea.
1459. A. Leitch, 8 Hampden Place, Mount Florida, Glasgow.
1240. Archd. Leitch, jun., Ardmaleish, Port Glasgow.
559. C. R. L. Lemkes, Rosehill, West Kilbride.
987. C. P. Lemon, H.M. Dockyard, Sheerness.
224. James Lemon, Lansdowne House, Castle Lane, Southampton
1042. Alex. Lennox, 34 Glasgow Street, Hillhead, Glasgow.
769. J. T. G. Leslie, 148 Hill Street, Garnethill, Glasgow.
935. L. R. Lester, Clifton on Dunsmore, Rugby.
1172. Lewis Levy, Hawthorn Lodge, 155 Finchley Road, London.
2090. Harry W. Lewin, 154 W. Regent Street, Glasgow.
139. David Lewis, Gorseinon, Glam.
792. Gething Lewis, 1 Pearson Place, Docks, Cardiff.
759. H. H. L. Lewis, The Foundry, Townmead Rd., Fulham, London, S.W.
66. J. T. Lewis, Gas Works, Wellingborough.

655. Wm. Lewis, 2 Cambridge Road, London, S.E.
140. W. R. Lewis, Gorseinon, Glam.
22. William Liddle, Hodbarrow Sea Wall Works, Millom.
461. E. H. Liebert, 115 Tweedale Street, Rochdale.
462. H. A. Liebert, 180 Drake Street, Rochdale.
2284. H. Lightbody, 3 Victoria Street, Westminster, London, S.W.
1104. J. B. Lightfoot, Kemnal Wood, Chislehurst, Kent.
1661. Joseph Lindley, Warsaw, Russia.
173. Robert S. Lindley, Godstone Place, Godstone, Surrey.
++ 674. C. C. Lindsay, 217 West George Street, Glasgow.
1811. James Lindsay, Fenton Hall, Stoke-on-Trent.
1097. Wm. F. Lindsay, 203 Nithsdale Road, Polloksbields, Glasgow.
1915. W. T. Lintern, 38 Chapel Terrace, Parkhead, Glasgow.
2218. James F. Lister, Rivers, Dursley.
141. Robert R. Lister, 11 Athol Road, Alexandra Park, Manchester.
1095. A. M. Little, 518 Springburn Road, Glasgow.
1423. G. Little, Smethwick.
1436. F. H. Livens, Oak House, Staithes, Yorks.
553. J. W. Liversedge, Surveyor and Waterworks Manager, Ashton-in-Makerfield, Lancs.
+ 3. George T. Livesey, Shagbrooke, Reigate.
1748. Archd. Livingston, Kinneil Collieries, Bo'ness.
1994. Wm. Livsey, Birch Mills Ironworks, Ashton-under-Lyne.
963. E. J. Ljunberg, Falun, Sweden.
1333. F. W. Llewellyn, Alsager, Near Stoke-on-Trent.
1652. E. H. Lloyd, c/o Jas. Mansergh, Bryngwy, Rhayader, Mid Wales.
44. G. C. Lloyd, 28 Victoria Street, London, S.W.
1503. Herbert Lloyd, Brecon Road, Builth, Wales.
1595. Samuel Lloyd, 90 Whitecross Street, London, E.C.
309. W. H. Lloyd, Hatch Court, Somerset.
+ 2328. F. J. Lobley, Council Office, Hale, Cheshire.
++ 977. J. Lobley, Richmond Terrace, Shelton, Hanley.
2071. Fred Lobnitz, Clarence House, Renfrew.
422. H. C. Lobnitz, Bay View, Millom, Cumberland.
493. A. Locher, Bowker Street 34, Higher Broughton, Manchester.
43. John Lockie, 7 Hermitage Place, Leith.
2345. F. M. Long, Electricity Co., Duke Street, Norwich.
1814. R. H. Longbotham, South Parade, Wakefield.
1284. John G. Longbottom, Sherwood, Scotstounhill.
+ 273 A. H. Longden, Stanton-by-Dale, Nottingham.
272. G. A. Longden, Stanton-by-Dale, Nottingham.
271. J. A. Longden, Stanton-by-Dale, Nottingham.
2016. Michael Longridge, 12 King Street, Manchester.
2017. James Lord, Town Hall, Halifax.
++ 1380. H. D. Lorimer, Kirklinton, Langside, Glasgow.
1094. Wm. Lorimer, Kirklinton, Langside, Glasgow.
775. G. F. Loudon, 10 Claremont Terrace, Glasgow.
2318. Prof. Henry Louis, Durham College of Science, Newcastle-on-Tyne.
1749. Geo. E. Louth, Great Western Railway, Reading.
1536. Geo. R. Love, 7 Wellington Place, Guilford, Surrey.
2281. R. T. Love, Stewarton.
1010. R. P. Lovell, 1 Church Terrace, Newton Heath, Manchester.
810. W. H. Loveridge, York Road, West Hartlepool.
1076. J. Lowe, Gas Works, Weymouth.
1427. R. Lowe, 85 Leslie Street, Pollokshields.
1250. James Lowe, c/o Mrs. Waddell, 33 Nithsdale Road, Glasgow.
513. D. A. Low, East London Technical Co., Mile End Rd., London,
307 S. R. Lowcock, Temple Courts, Birmingham.

1424. T. B. Loxley, 3 St. John's Terrace, Wakefield.
1509. W. Lumley, 2 Claremont, Claremont Place, Gateshead-on-Tyne.
1168. T. T. M. Lumsden, 46 Queen Street, Edinburgh.
1100. Jas. L. Lumsden, 18 Douglas Street, Kirkcaldy.
318. Clifton Lund, Town Hall, Cleckheaton
2175. N. D. Lupton, 16a Sholebroke Avenue, Leeds.
1815. Com. Luigi Luiggi, Esmeralda, 22, Buenos Aires.
++ 2080. W. J. Luke, c/o John Brown & Co., Ltd., Clydebank.
961. Hugh D. Lusk, Larch Villa, Annan.
855. Jas. Lusk, Orchard View, Hamilton Road, Motherwell.
955. John Lyall, 33 Randolph Gardens, Partick.
1305. H. T. Lyon, 57 Onslow Square, London, S.W.

M

597. D. Macalister, Overton Cottage, Greenock.
1663. John H. Macalpine, Viewfield, Kilmalcolm.
1043. Alex. M'Ara, 19 Dundonald Road, Kelvinside.
1108. Wm. M'Aulay, 17 St. Andrews Drive, Pollokshields, Glasgow.
13. Malcolm A. E. MacBean, Dunnolly, West Kilbride.
557. Donald M'Bean, Speedwell Hotel, Rochester, Kent.
++ 24. L. MacBrayne, 119 Hope Street, Glasgow.
588. David M'Call, 10 Rosslyn Terrace, Kelvinside.
1400. R. B. MacCall, 145 Renfrew Street, Glasgow.
927. H. MacColl, 4 Kirkleston Drive, Bloomfield, Belfast.
691. Geo. H. M'Cowat, 8 Regent Park Square, Strathbungo, Glasgow.
1027. Jas. M'Cracken, 3 Rosemount Terrace, Ibrox.
876. Wm. M'Crae, Gas Works, Dundee.
616. Wm. M'Culloch, Linkieburn House, Muirkirk.
524. F. W. M'Cullough, Waterworks Engineer, Belfast.
++ 2011. Alex. B. M'Donald, 79 Montgomerie St., N. Kelvinside, Glasgow.
2178. D. H. Macdonald, Brandon Works, Motherwell.
284. John MacDonald, Bonaly, Clynder, Roseneath.
768. S. Macdonald, 1 Colebrooke Place, Glasgow.
371. Thos. Macdonald, 47 Glencairn Drive, Pollokshields.
++ 762. D. M'Dougall, Burnlea, Greenock.
2329. P. R. M'Dougall, 70 South Street, Greenock.
282. John M'Elligott, 4 Victoria Drive, Mount Florida, Glasgow.
615. G. J. Macfadzean, 3 Grosvenor Terrace, Middlesbro'.
++ 763. Geo. M'Farlane, Dunsloy, Bellahouston, Glasgow.
893. John M'Farlane, 330 Dennistoun Gardens, Alexandra Park, Glasgow.
1630. Walter Macfarlane, Kelvin, Hollies Drive, Wednesbury, So. Staffs.
1180. D. Macfie, Milton House Works, Edinburgh.
449. D. B. M'Geoch, Lilybank, Port Glasgow.
2145. Wm. M'Geoch, Jun., 56 Coventry Road, Birmingham.
2092. W. C. M'Gibbon, 108 Forth Street, Pollokshields, Glasgow.
+ 25. James M'Gilchrist, Gas Works, Dumbarton.
1579. Thomas M'Gill, Electricity Supply Station, Park Street, Dover.
783. John A. M'Gilvray, 25 Hutton Drive, Govan.
1327. Archibald M'Glashan, Beechcroft, Clifton Avenue, West Hartlepool.
1031. John M'Gregor, Coatbank Engine Works, Coatbridge.
1918. Thos. M'Gregor, Mosesfield Terrace, Springburn, Glasgow.
825. H. A. M'Guffie, Aldred House, The Crescent, Salford.
1041. John H. M'Ilwaine, 43 Waring Street, Belfast.
894. J. B. M'Indoe, Electricity Works, Coatbridge.
567. D. M'Intosh, Dunglass Cottage, Bowling, N.B.
++ 121. J. F. M'Intosh, 67 Albert Road, Crosshill, Glasgow.

452. J. P. M'Intosh, 23 Bank Street, Aberdeen.
2336. J. H. A. M'Intyre, 2 Ashgrove Terrace, Partickhill.
++2152. T. W. M'Intyre, Glen Tower, Kelvinside.
932. Alex. Mackay, 55 Grange Road, Edinburgh.
1714. Francis M'Kean, 53 Waterloo Street, Glasgow.
1084. Allan M'Keand, 1 St. James' Terrace, Hillhead, Glasgow.
++2144. J. M'Kechnie, Vickers, Son & Maxim, Ltd., Naval Construction Works, Barrow-in-Furness.
1293. David M'Kenzie, County Buildings, Dunfermline.
2033. John M'Kenzie, Speedwell Iron Works, Coatbridge.
829. T. B. Mackenzie, 342 Duke Street, Glasgow.
2298. Thos. R. Mackenzie, 3 Huntly Gardens, Glasgow.
352. James M'Kerlie, 7 Duffield Road, Irlams o' th' Height, Manchester.
1622. Wm. Mackie, Lilybank, Port-Glasgow.
++2125. W. A. Mackie, Govan Shipbuilding Yard, Govan.
1361. P. A. M'Killop, 104 North Hanover Street, Glasgow.
1532. R. M'Killop, Barnhill Cottage, Perth.
739. Wm. M'Kinnel, 234 Nithsdale Road, Pollokshields.
1923. C. F. Maclaren, Stenton Iron and Steel Works, Wishaw.
819. H. M'Laren, Midland Engine Works, Leeds.
1203. John M'Laren, Midland Engine Works, Leeds.
921. John M'Laren, Manager, Gas Works, Duns, N.B.
++ 694. J. F. Maclaren, Eglinton Foundry, Glasgow.
1206. J. M. MacLaren, 62 Sydney Street, South Kensington, London, S.W
968. R. M'Laren, 19 Morningside Park, Edinburgh.
++1750. Robert Maclaren, Eglinton Foundry, Glasgow.
586. W. A. M'Laren, Royal Exchange, Leeds.
1054. Wm. M'Laren, Cordoba, Bothwell.
746. J. D. M'Lauchlan, 21 Young Street, Edinburgh.
2041. Duncan M'Laurin, Cartside Works, Millikenpark.
186. James H. Maclaurin, Tigh-na-ghrian, Ayr.
1026. Alex. MacLay, Camptower, Bearsden.
1824. David M. Maclay, Dunourne, Motherwell.
++ 944. J. P. Maclay, 13 Park Terrace, Glasgow.
++1825. Wm. Maclay, Thornwood, Langside, Glasgow.
554. John Maclean, 19 University Avenue, Glasgow.
++1712. Prof. Magnus Maclean, 51 Kersland Terrace, Glasgow.
671. D. M'Lellan, 53 Thornwood Drive, Partick.
1995. And. J. M'Lelland, 115 St. Vincent Street, Glasgow.
2239. G. S. MacLellan, Clutha Works, Glasgow.
1520. W. T. MacLellan, 129 Trongate, Glasgow.
274. W. MacLeod, 4 Colebrooke Terrace, Hillhead.
903. J. M'Mahon, 18 Imperial Terrace, Blackpool.
++1704. Walter George Macmillan, 28 Victoria Street, London, S.W.
1476. W. M. M'Millan, The Hotel, Carr Bridge, Inverness-shire.
1353. Alex. Macmorran, Lochiel Arms Hotel, Banavie, N.B.
1456. Geo. E. J. M'Murtrie, Radstock, Near Bath.
1071. Jas. M'Murtrie, Radstock, Bath.
1647. Jas. M'Nair, Norwood, Prestwick Road, Ayr.
722. C. J. M'Naught, Moorhurst, Kents Bank, Lancashire.
355. Bedford M'Neill, 25a Old Broad Street, London, E.C.
1826. John M'Neil, Colonial Iron Works, Helen Street, Govan.
++1682. Andrew M'Onie, Cessnock Engine Works, Copeland Road, Govan.
1442. R. B. Macouat, Arden, Park Gardens, Partick.
362. A. MacPherson, Gas Co. Office, Kirkcaldy.
986. Angus Macpherson, 4 St. Vincent Terrace, Coatham, Redcar.
600. Charles M'Pherson, 25 Victoria Street, Aberdeen.
1375. M. Macpherson, 86 Stevenson Drive, Shawlands, Glasgow.

2018. A. P. Stanley MacQuisten, 33 Renfield Street, Glasgow.
898. Grieve Macrone, St. Aubyns, Basingstoke, Hants.
2019. Wm. M'Whirter, 9 Walworth Terrace, Glasgow.
2154. Andrew M'William, 12 Marlborough Road, Sheffield.
795. Wm. L. Madgen, Surrey House, Victoria Embankmt., London, W.C.
1575. H. P. Maffiola, 21 Wellington Street, Waterloo, Liverpool.
1959. Romain Maievesky, Tikhievin, Province de Novgorod, Russia.
1252. R. B. Main, Broomrig, Dollar.
157. Cree Maitland, Ocean Chambers, 190 West George St., Glasgow.
219. Colonel E. D. Malcolm, Auchnamara, Lochgilphead.
1465. John Malcolm, 6 Waterloo Place, London, S.W.
1816. S. Malcolm, 93 Jesmond Road, Newcastle-on-Tyne.
353. John Mallinson, Town Hall, Skipton-in-Craven.
23. G. Mann, 10 Polmuir Road, Aberdeen.
2156. John Mann, 137 West George Street, Glasgow.
2120. John Mann, Jun., 137 W. George Street, Glasgow.
1653. E. L. Mansergh, c/o Jas. Mansergh, Bryngwy, Rhayader, Mid Wales.
+ 1651. Jas. Mansergh, Bryngwy, Rhayader, Mid Wales.
1654. Walter L. Mansergh, c/o Jas. Mansergh, Bryngwy, Rhayader, Mid Wales.
++ 833. Jas. Manson, G. & S.W. Railway, Kilmarnock.
1733. Sydney H. March, Stradsett, 16 Silverdale Rd., Chorlton-cum-Hardy, Nr. Manchester.
1256. F. G. Marley, 237 Albert Road, Jarrow-on-Tyne.
925. T. E. G. Marley, Monkscroft, St. Bees.
2030. R. Marriott, Broomloan Road, Govan.
++ 1306. D. Marshall, 18 Park Terrace, Glasgow.
1164. J. G. Marshall, Norwich Union Chambers, Congreve Street, B'ham.
2271. John Marshall, 2 York Terrace, Cheltenham.
941. R. Marshall, 12 Broughton Road, South Shields.
400. W. B. Marshall, Richmond Hill, Edgbaston, Birmingham.
179. Arthur J. Martin, Bradninch House, Exeter.
369. David Martin, 2 Thornwood Terrace, Partick West, Glasgow.
+ 799. Edw. P. Martin, Dowlais, Glamorganshire.
909. Wm. C. Martin, Heathbank, Kelvinside Gardens.
142. George R. Martyn, Skelmorlie, Stour Park, Newport, Mon.
296. Harold F. Massey, c/o B. & S. Massey, Openshaw, Manchester.
297. Leonard F. Massey, c/o B. & S. Massey, Openshaw, Manchester.
234. C. Masterman, Flavia Terrace, South Shields.
1996. A. J. Mather, Glendair, Heaton Grove, Bradford.
1401. G. R. Mather, Botlea, Wellingborough.
778. Cha. Mathew, Town Hall, Ryde, Isle of Wight.
++ 781. D. A. Matheson, 15 Royal Terrace West, Glasgow.
1257. Donald Mathieson, 30 Jackson Street, Sunderland.
1819. S. Matinoff, St. Petersburg.
1818. J. Matthews, Forth Bank Works, Newcastle-on-Tyne.
+ 2053. Wm. Matthews, 9 Victoria Street, London.
++ 892. Henry A. Mavor, 3 Windsor Circus, Glasgow.
++ 1697. Sam Mavor, 37 Burnbank Gardens, Glasgow.
906. R. L. Maw, 18 Addison Road, Kensington, London, W.
+ 375. Wm. H. Maw, 35 and 36 Bedford Street, Strand, London, W.C.
+ 412. E. G. Mawbey, Town Hall, Leicester.
1664. James Maxton, 4 Ulster Street, Belfast.
143. Thos. Maxwell, 15 Ashfield Terrace East., Newcastle-on-Tyne.
231. Wm. W. Maxwell, 36 Crown Street, Newcastle-on-Tyne.
2004. Arthur May, 24 Bride Lane, Fleet Street, London, E.C.
2093. Walter May, 10 Blenheim Road, Bedford Park, London, W.
624. W. W. May, Woodbourne, Partickhill, Glasgow.

1820. Henry Mechan, c/o Messrs. Mechan & Sons, Scotstoun, Glasgow.
2020. Charles Meiklejohn, Craigside, Rugby, Warwickshire.
383. Jas. Meldrum, 10 Victoria Street, Westminster, London, S.W.
859. J. F. Melling, Cyclops Works, Sheffield.
2190. Samuel Melling, Ince Forge, Wigan.
1300. Thos. Melling, Parbold, via Southport.
++ 2072. William Melville, Dunloskin, Dumbreck.
2361. Carlos Mendizabal, Sociedad de Altos Hornos, Bilbao, Spain.
++ 1103. John Menzies, Eastbank, High Blantyre.
728. Jas. B. Mercer, New Bank, Lower Broughton Rd., Manchester.
2253. C. S. Metcalfe, 24 Croft Avenue, Sunderland.
577. S. Meunier, Gas Works, Stockport.
2358. Jos. L. Meyer, Papenburg, Ems, Germany.
1049. A. C. Meyjes, 42 Cannon Street, London, E.C.
2337. A. Middeldorff, Worcester, Mass., U.S.A.
242. J. T. Middleton, The Grange, Grange Road, Ealing.
2181. R. A. Middleton, 34 Rothbury Terrace, Heaton, Newcastle-on-Tyne.
1821. Reginald E. Middleton, 17 Victoria Street, London, S.W.
1278. Ernest J. Miles, Borough Engineer's Office, West Hartlepool.
690. Jno. S. Millar, 22 White Street, Partick, Glasgow.
162. R. Millar, 6 Colebrooke Street, Hillhead, Glasgow.
1668. Thomas Millar, 19 Beverley Terrace, Cullercoats, Northumberland.
2195. E. H. Millard, City of Durham Gas Co., 18 Claypark, Durham.
2147. David S. Miller, 8 Royal Crescent, Glasgow, W.
144. H. W. Miller, 18 Kensington Court Place, London, W.
1378. John Miller, Etruria Villa, South Govan.
1919. John D. Miller, Rosehall Colliery, Coatbridge.
766. John F. Miller, Greenoakhill, Broomhouse.
391. Robt. F. Miller, 109 Bath Street, Glasgow.
377. F. O. Mills, 31 Lansdowne Road, East Croydon, Surrey.
460. Thomas Mills, Longdown Lodge, Sandhurst, Berks.
754. W. H. Mills, Nurney, Glenagarey, Co. Dublin.
435. Douglas Milne, 10 Queen's Road, Aberdeen.
1416. Jas. Milne, Muirend, Colinton, Midlothian.
663. W. B. Mimmack, Gas Works, St. Mary Craig, Kent.
1916. Charles Misselhausen, 19 St. John's Park, Blackheath, London, S.E.
++ 1231. George A. Mitchell, 5 West Regent Street, Glasgow.
703. H. E. Mitchell, The Ivy House, Christchurch, Hempstead, N.W.
478. James Mitchell, 19 Justice Mill Lane, Aberdeen.
2219. John Mitchell, 98 Powis Place, Aberdeen.
2315. John H. Mitchell, Bellvue, Uddingston.
1158. Thos. Mitchell, Annanbank, 17 Dumbreck Road, Glasgow.
1645. Wm. Mitford, 6 Newcomen Terrace, Coatham, Redcar.
1332. A. D. Mitton, Oakwood, Walkden, Nr. Manchester.
2173. Thomas E. Mitton, c/o Hunt & Mitton, 14 Oozell Street, North, Birmingham.
1640. Wm. Moat, Johnson Hale, Eccleshall, Staffordshire.
119. C. H. Moberley, 33 Bennet Park, Blackheath, London, S.E.
1548. A. Mogoutchy, Vitegra, via St. Petersburg, Russia.
+ 1349. Sir G. L. Molesworth, The Manor House, Bexley, Kent.
1271. H. A. Mollison, 30 Balshagray Avenue, Partick.
++ 203. James Mollison, 30 Balshagray Avenue, Partick.
936. J. M. Moncrieff, 1 St. Nicholas Buildings, Newcastle-on-Tyne.
440. Geo. Moncur, Engineer in Chief's Office, Gt. North of Scotland Railway, Aberdeen.
1209. J. W. Moncur, Borough Surveyor, Sunderland.
1301. J. M. V. Money-Kent, Lime Tree House, Twickenham.
1075. Edw. W. Monkhouse, 14 Old Queen St., Westminster, London, S W.

1920. F. Monks, Messrs. Monks, Hall & Co., Ltd., Warrington.
2171. Geo. Monteath, Taynuilt, Newton St. Boswells.
1336. J. W. Montgomery, Silverdale, Staffordshire.
1414. H. Moore, 49 Roslea Drive, Dennistoun, Glasgow.
++ 2073. R. T. Moore, B.Sc., 13 Clairmont Gardens, Glasgow.
705. T. Ivor Moore, Craiglea, Woking.
322. Thomas L. Moore, Millfield Foundry, Belfast.
916. Wm. Moore, Springvale House, Ettingshall, Nr. Wolverhampton.
2317. James More, Jun., 13 Drummond Place, Edinburgh.
87. Edwd. F. Morgan, Town Hall, Croydon.
1961. J. T. Morgan, 2 Morlais Street, Dowlais, Glam.
904. D. B. Morison, c/o Richardson, Westgarth & Co., Hartlepool.
853. W. B. Morison, 7 Rowallan Gardens, Broomhill, Glasgow.
430. W. S. Morland, Gas Works, Hempstead, Gloucester.
1922. J. E. Morley, Iron and Steel Founders, Hebburn-on-Tyne.
196. B. H. Morphy, 29 Deodar Road, Putney, London, S.W.
1669. Geo. E. Morrell, The Laurels, Belvedere, Kent.
1696. David K. Morris, The University, Birmingham.
2294. John Morris, Gwalia House, Gorseinor, South Wales.
1025. A. M. Morrison, Merchiston, Scotstounhill, Glasgow.
871. Wm. Morrison, 7 Maurice Place, Edinburgh.
++ 677. Wm. Morrison, 41 St. Vincent Crescent, Glasgow.
2021. Wm. Morrison, 11 Sherbrooke Avenue, Pollokshields, Glasgow
45. W. Murray Morrison, Foyers, Lochness.
1162. And. Home Morton, 130 Bath Street, Glasgow.
1163. David Home Morton, 130 Bath Street, Glasgow.
214. Hugh J. Morton, 128 Wellington Street, Glasgow.
668. Jas. Morton, Manor Park, Coatbridge.
427. John Morton, Gas Works, Ashford, Kent.
4. Robert Morton, 27 Hamilton Terrace, London, N.W.
212. Robert Morton, 237 West George Street, Glasgow.
2143. Alessandro Moschini, S. Nicolò, Padova, Italy.
1147. Edmund Mott, Neilson Cottage, 25 Albert Road, Langside.
1061. J. C. Mount, Town Hall, Lancaster.
301 Montague B Mountain, Jesmond, Southborough Road, Chelmsford, Essex.
981. M. Mowat, jun., Pitmain Lodge, Granville Park, Blackheath, London, S.E.
++ 1962. Archd. H. Mowbray, Wellhall, Hamilton.
1117. John Y. Moyes, 12 Ruthven Street, Glasgow.
667. A. A. Muir, 189 Renfrew Street, Glasgow.
666. James Muir, 189 Renfrew Street, Glasgow.
558. J. E. Muir, 45 West Nile Street, Glasgow.
1381. J. F. Muir, 8 Westminster Gardens, Glasgow, W.
457. J. R. Moncrieff Muir, c/o H. & C. Grayson, Ltd., 179 Regent Road, Liverpool.
605. R. W. Muir, 275 Golfhill Drive, Dennistoun.
120. William Muirhead, 37 West George Street, Glasgow.
1823. Alexander Muller, St. Petersburg.
2169. Thos. N. Muller, c/o E. C. Muller & Co., Middlesbrough.
1963. Edwin Richard Mumford, Lynton House, Dumbarton.
951. C. Mumme, 30 Newark Street, Greenock.
538. James Munce, Asst. City Surveyor, Town Hall, Belfast.
217. Walter H. Mungall, Croftweit, Crieff.
++ 1079. R. D. Munro, 111 Union Street, Glasgow.
453. A. Munyard, 6 Keir Street, Pollokshields.
1917. J. Murdoch, 7 Park Circus Place, Glasgow.
317 S L. Murgatroyd, Shelthorpe Cottage, Loughborough, Leicestershire.

1964. Philip Edward Murphy, 132 Philip Lane, South Tottenham, Lond.
1965. Angus Murray, Strathroy, Dumbreck.
1593. Charles W. Murray, 52 Marmora Road, Honor Oak, London, S.E.
++ 1316. F. B. Murray, 3 Clarence Drive, Kelvinside, Glasgow.
926. Jas. Murray, Helenview, Gourock.
1573. Richard Murray, 52 Albert Drive, Pollokshields, Glasgow.
241. T. R. Murray, Mayfield, Melksham, Wilts.
2221. Wm. Murray, 11 Leicester Street, Hull.
1686. Walter M. Musgrave, Globe Iron Works, Bolton.
2200. W. Musswitz, Schuckert & Co., Nuremberg, Bavaria.
106. W. B. Myers-Beswick, Gristhorpe Manor, Filey, Yorkshire.

N

1678. Nagao, c/o Wm. Brown, Esq., Meadowflat, Renfrew.
969. Yosohachi Nakajima, I.J.N., 5 Montgomerie Cottage, Scotstoun, Glasgow.
1827. H. Nakayama, Engineering College, Tokyo, Japan.
1522. Francis H. Nalder, 52 South Terrace, Littlehampton, Sussex.
++ 1709. Henry M. Napier, Wilton House, Bowling.
1445. J. S. Napier, Broompark, Denny, N.B.
861. T. Nash, 9 Nether Edge Road, Sheffield.
2306. F. F. Neall, Dock Office, Leith.
1828. C. T. Needham, Needham Chambers, Old Millgate, Manchester.
1829. John Neilson, 53 Bothwell Street, Glasgow.
1810. D. M. Nelson, 14 W. Princes Street, Glasgow.
1529. Wm. M. Nelson, c/o Mrs. Cameron, 40 Brisbane Street, Greenock.
1535. George Ness, 128a Queen Victoria Street, London, E.C.
325. R. S. Newbold, c/o Gas Works, Freemantle, W. Australia.
2005. Leonard Newitt, 4 Belgrave Parade, Newcastle-on-Tyne.
911. A. Newlands, Highland Railway, Inverness.
543. A. J. Newport-Kennett, 61 Barrfield Road, Pendleton, Manchester.
376. T. B. L. Newstead, Ivy Villa, Newbold Road, Rugby.
988. E. B. B. Newton, 125 Monton Road, Eccles, Lancashire.
2111. Benjamin Nicholas, Rockfield House, Pontypool, Mon.
1637. H. Nicholson, Stockton Street, Manchester.
1377. J. C. Nicholson, Collingwood Street, Newcastle-on-Tyne.
1830. John S. Nicholson, North View, Mowbray Road, South Shields.
1176. R. G. Nicol, Harbours Engineer's Office, Aberdeen.
145. Dr. J. T. Nicolson, Nant-y-Glyn, Marple.
1263. James Nisbet, Helenslea, Uddingston, W.
++ 2322. Thos. Nisbet, City Chambers, Glasgow.
1547. Thomas O. Niven, 19 Ann Street, Hillhead, Glasgow.
246. Joseph Nodder, Ash Lea, Crabtree, Sheffield.
+ 1392. Rear-Admiral Sir Gerard H. Noel, 5 Chester Place, Hyde Park Sq., London, W.
841. C. G. Norris, 504 Stockport Road, Longsight, Manchester.
1831. W. G. Norris, Coalbrookdale, Shropshire.
1491. Edward P. North, 220 West 57th Street, New York.
1369. W. H. Northcott, Hatcham Iron Works, Pomeroy Street, New Cross Road, London, S.E.
1966. Arthur Norton, 104 Stanmore Road, Edgbaston, Birmingham.
1924. T. Nowlan, Pittgwendly Foundry and Engineering Works, Newport.
813. John Nuttall, Oughtibridge, Nr. Sheffield.

O

858. R. Oakden, jun., 41 Kirkgate, Newark.
180. William O'Brien, 21 Ibrox Terrace, Ibrox.
2186. Wm. P. O'Neil, Chief Engineer, Midland Railway, Ireland.
639. J. W. Onion, Wainfelin, Pontypool.
1925. W. J. Onions, Parkdale, Beeches Road, West Bromwich.
1121. A. W. Onslow, 8 Portland Terrace, Eglinton Rd., Shooters Hill, London, S. E.
122. Reginald T. Orme, Woodlands, Uttoxeter New Road, Derby.
761. J. W. Ormiston, 213 St. Vincent Street, Glasgow.

P

994. Geo. S. Packer, Atlas Works, Sheffield.
2191. H. F. Packham, Works and Engineer's Office, Lower Ham Road, Kingston-on-Thames.
458. Berkeley Paget, 2 Laurence Pountney Hill, London, E.C.
2240. D. Page, Clun House, Surrey Street, Strand, London.
1832. C. Paillard-Duclere, Commission Européenne du Danube, Galatz, Roumania.
107. C. B. Palmer, Wardley Hall, Nr. Newcastle-on-Tyne.
191. Henry Palmer, The Manor House, Medomsley.
193. Philip H. Palmer, 11 Grosvenor Crescent, St. Leonards-on-Sea.
1833. Marquis Pappalepore, Commission Européenne du Danube, Galatz, Roumania.
1045. J. C. Pardoe, Kirklands, Barry, Glam.
++ 1620. Edward H. Parker, 11 Strathmore Gardens, Hillhead, Glasgow.
866. John Parker, City Engineer, Hereford.
1212. Joseph Parker, Cardenden, Fife.
715. B. Parkes, Promenade, Castletown, Isle of Man.
1496. John I. Parkes, Mayfield, Harborne Rd., Edgbaston, Birmingham.
348. John Parkin, 9 Cambridge Road, Blackpool.
2257. Richd. M. Parkinson, 93 Lincoln Road, Peterbond.
2040. Wm. W. Parkinson, 94 White Gate Drive, Blackpool.
511. D. A. Parkyn, The Gerrards, Gee Cross, Nr. Manchester.
268. W. J. Parkyn, Oakfield Hall, Dukinfield, W. Manchester.
975. Christopher Parnaby, Blackhill, Co. Durham.
281 E. Parry, 28 Park Row, Nottingham.
1214. Joseph Parry, 7 South Terrace, Victoria Rd., Peel Causeway, Nr. Manchester.
1165. Joseph Parry, Municipal Offices, Liverpool.
1834. Wartam Pastakoff, St. Petersburg.
239. John Paterson, Belle Isle Place, Working, Cumberland.
1835. F. Stark Paterson, 6 Broomhill Gardens, Partick.
+ 2050. T. O. Paterson, Gas Works, Birkenhead.
2212. Walter L. C. Paterson, Elmwood Terrace, Jordanhill.
++ 2075. William Paterson, 25 Ingram Street, Glasgow.
1169. Wm. A. Paterson, 47 Castle Street, Edinburgh.
209. Prof. George Paton, Royal Agricultural College, Cirencester.
+ 2289. James Paton, Municipal Offices, Plymouth.
189. Andrew C. Patrick, Engineer, Johnstone.
67. Anthony Patterson, 9 Glossop Terrace, Cardiff.
609. Jas. Patterson, Maryhill Iron Works, Glasgow.
623. Jas. Patterson, 18 Belmont Gardens, Glasgow.
1289. And. Paul, Kirkton, Dumbarton.
1056. F. W. Paul, Greenbank, Lawton, Stoke-on-Trent.
1967. James Paul, Levenford Works, Dumbarton.
++ 1460. M. Paul, Alcluith, Dumbarton.

2099. W. J. Paulin, 24 Oxford Street, Newcastle-on-Tyne.
68. H. Payne, 79 Arbuthnot Road, New Cross, London, S.E.
1968. Wm. John Frederick Payne, Ackton Hall Colly., Featherstone, Pontefract.
582. H. C. Peake, Walsallwood, Walsall.
398. R. C. Peake, Cumberland House, Redbourn, Herts.
1609. E. Peakes, of E. Peakes & Co., Atlas Iron Works, West Bromwich.
1317. F. W. Pearce, 10 Sandy Coombe Road, East Twickenham, Middlesex.
349. Wm. H. Peard, 2 Ashfield Park, Terenure, Co. Dublin.
384. C. H. Pearson, 86 Cannon Street, London, E.C.
914. F. H. Pearson, 27 Scale Lane, Hull.
1970. James J. Peck, 52 Randolph Gardens, Glasgow.
1047. N. E. Peck, Newington, Jordanhill, Glasgow.
1836. General Pencovici, Commission Européenne du Danube, Galatz, Roumania.
1926. Vaughan Pendrid, "The Engineer," 33 Norfolk Street, Strand,
2029. D. A. Penman, 53 Waterloo Street, Glasgow.
2101. L. Penny, Members Mansions, Victoria Street, London, S.W.
561. William Pepper, West Villas, Stockton-on-Tees.
750. Wm. F. Pepper, 5 Selborne Terrace, Gateshead-on-Tyne.
26. H. L. Percy, 13 Hanger Lane, Ealing, W.
2340. T. M. Percy, Wigan Coal and Iron Co., Wigan.
1073. John Perks, The Elms, Woodville, Burton-on-Trent.
895. Wm. J. Perkins, 17 Victoria Street, Westminster, London, S.W.
1389. T. F. Perman, 4 Sandyford Place, Glasgow.
69. Arthur Pernolet, 20 Mount Street, Manchester.
1610. John E. Perry, Albany Chambers, Lichfield Street, Wolverhampton.
823. W. H. Perry, 36 Westbourne Street, Stockton-on-Tees.
742. J. A. Peterkin, 13 Swinley Road, Wigan.
2246. F. Petit, Rochefort S. Mer, France.
1091. Thomas A. Petrie, 66 Dee Street, Aberdeen.
1140. Geo. Pettigrew, Boundary Road Works, Middlesbrough-on-Tees.
974. John Pettigrew, Fairmount, 40 The Esplanade, Greenock.
973. W. F. Pettigrew, Friars Dene, Abbey Road, Barrow-in-Furness.
1120. Wm. L. Philip, 7 Sherbrooke Avenue, Pollokshields, Glasgow.
1517. Charles D. Phillips, Emlyn Engineering Works, Newport, Monmouth.
198. John R. Phillips, 54 Oak Road, Crumpsall, Manchester.
2268. Wm. Philipson, 27 Pilgrim Street, Newcastle-upon-Tyne.
817. E. Picker, Newbegin, Beverley, Yorks.
337. Jonathan Pickering, 7 Ashgrove Terrace, Partickhill.
1341. W. Pickersgill, 398 Gt. Western Road, Aberdeen.
2348. G. H. Pickles, Albert Terrace, Burnley.
1032. T. F. Pigot, 14 Fitzwilliam Place, Dublin.
316. H. Pilkington, Sheepbridge Iron Works, Chesterfield.
299. Oliver S. Pilkington, Bryn Cregin, Deganwy, near Llandudno.
+ 540. S. S. Platt, Moss House, Rochdale.
500. Wm. Platts, The Brooms, Sheffield.
1319. E. Martin Player, The Quarr, Clydach, R.S.O., Glamorganshire.
1318. W. J. Percy Player, The Quarr, Clydach, R.S.O., Glamorganshire.
277. Wm. Poland, King's Bench Wall, Southwark, London, S.E.
291. David Pollock, 128 Hope Street, Glasgow.
847. Henry Pooley, Homestead, Liscard, Cheshire.
846. John S. Pooley, Eblana, Glenburn Road West, Bearsden.
434. John W. Porter, Grandholm Cottage, Persleyden, Aberdeen.
2290. Richard Porter, Town Hall, Wakefield.
2323. R. Portheim, Tay Works, Bonnington.
2187. S. J. Powell, 7 Allison Grove, Dulwich Common, London, S.E.
+ 46. Sir W. H. Preece, Gothic Lodge, Wimbledon.

1397. W. J. Press, Berrow Road, Burnham, Somerset.
2088. James Prestwick.
1174. A. J. Price, Council Offices, Lytham, Lancs.
+ 108. John Price, City Surveyor, Birmingham.
1611. Jos. Price, 125 Bunhill Row, London, E.C.
735. W. E. Price, Gas Works, Hampton Wick, Kingston-on-Thames.
726. C. H. Priestley, 20 Plas Turton Gardens, Cardiff.
1927. Jas. Procter, Wrockwardine Villa, Oakingate, Shropshire.
397. John H. Proctor, 22 Hawthorn Terrace, Newcastle-on-Tyne.
70. John V. Pugh, Primrose Hill House, Coventry.
442. J. T. Pullon, 75 Victoria Road, Headingly, Leeds.
1837. D. Purves, 3 Park Crescent, Southport.
1210. J. A. Purves, 4 Wardie Avenue, Edinburgh.
1242. Joseph Pym, Blackbrook House, Belper.

Q

405. H. J. Quicke, Belle Vue, Ryton-on-Tyne.

R

2160. Chas. E. Raeburn, 1 Hillhead Street, Glasgow.
1175. Jas. Railton, Holme Lea, Penarth, Glamorganshire.
1612. George Raine, 48 Side, Newcastle-on-Tyne.
1613. John Raine, 48 Side, Newcastle-on-Tyne.
939. S. B. Ralston, 34 Gray Street, Glasgow.
71. L. M. Rampal, 60 Lebanon Gardens, Wandsworth, London, S.W.
331. Joseph Randall, Warren Lane Works, Woolwich.
413. J. T. Randall, Gas Offices, Southend, Essex.
83. John Rankin, Ravenslea, Bothwell.
1838. Matthew Rankin, 3 Wilton Crescent, Glasgow.
2220. Thos. J. M. Rannie, 104 Leadside Road, Aberdeen.
356. G. F. Ransome, Engineer, Liverpool.
1462. R. A. Raphael, 150 Renfrew Street, Glasgow.
917. Prof. Auguste Rateau, 10 Quai d'Orsay, Paris.
444. B. Rathmell, 2 Eaton Avenue, Liscard, Cheshire.
701. Batard Razeliere, 14 Rue Montaux, Marseilles.
497. R. Read, Guildhall, Gloucester.
1355. T. P. Reay, Westwood Lodge, Leeds.
1928. J. F. Redman, Wilsons and Furness-Leyland Line, Ltd., 38 Leadenhall Street, London, E.C.
2022. D. Sims Rees, Glonllynor House, Maisteg, Glam., S. Wales.
1971. J. S. Reeves, Bilston Gas Works, West Bromwich.
1064. A. T. Reid, 10 Woodside Terrace, Glasgow.
1259. David J. Reid, York House, Church Street, Inverness.
++ 1373. H. Reid, Belmont, Springburn, Glasgow.
2292. James Reid, Conservative Club, Glasgow.
1029. John Reid, 7 Park Terrace, Glasgow.
109. R. M. Reid, 48 Barnton Street, Stirling.
856. Robert S. Reid, 39 Melville Street, Pollokshields.
946. James Renfrew, Gas Works, Langbank.
158. D. Rennie Jun., 109 Whitehall Street, Dennistoun.
347. Major Renny, R.A., 13 The Common, Woolwich.
261. Hans Renold, 3 Brook Street, Manchester.
501. S. Rentell, 15 Woodland Gardens, Muswell Hill, London.

842. B. M. Renton, Midland Works, Sheffield.
1326. And. Reside, 38 Brooke St., Rastrick, Brighouse, Yorks.
838. Jas. H. Rew, Victoria Place, Airdrie.
628. A. M. Reynolds, Arlington House, Trinity Road, Birchfield, Birmingham.
2327. W. G. Rhodes, Tower Chambers, Manchester.
651. Arthur W. Richards, Stapylton Villa, South Bank, R.S.O., Yorkshire.
++1539. E. J. W. Richards, The Cottage, Glengarnock, N.B.
+ 72. E. Windsor Richards, Plas Llecha, Cærleon, Mon.
1676. W. H. Richards, Vulcan Foundry, Darlaston.
612. Wm. Richards, 30 Alexandria Road, Hornsey, W.
1660. H. Richardson, Council House, Handsworth, Birmingham.
+ 110. Sir Thos. Richardson, Kirklevington Grange, Yarm.
678. Wigham Richardson, Wingrove House, Newcastle-on-Tyne.
+ 73. T. Hurry Riches, Taff Vale Railway, Cardiff.
744. Ch. Richmond, c/o F. Hills, Esq., Northleigh House, Yarm-on-Tees.
++1505. Sir David Richmond, Broompark, Pollokshields, Glasgow.
1929. Jas. Richmond, 24 Sutherland Terrace, Hillhead, Glasgow.
++1105. J. R. Richmond, 1 Kilmorie Terarce, Pollokshields.
1802. A. A. Rickaby, 27 Olive Street, Sunderland.
1989. John Rickie, "Argaith," Dumbreck.
772. W. G. Riddell, 155 Hyndland Road, Glasgow.
2310. G. E. Ridgway.
1255. George D. Ridley, 31 Durham Road, Spennymoor.
1839. J. C. Ridley, Swalwell Steel Works, Newcastle-on-Tyne.
1840. J. C. Ridley, jun., Swalwell Steel Works, Newcastle-on-Tyne.
1080. N. B. Ridley, c/o Crosier Stephens & Co., 2 Collingwood Street, Newcastle-on-Tyne.
568. C. H. Ridsdale, Wilton Lodge, Southfield Road, Middlesbro'.
1523. John Ridyard, Hilton Bank, Little Hulton, Bolton-le-Moors.
321. Walter Riggs, 16 Davies Street, Berkeley Square, London, W.
1841. M. E. Rigo, Directeur de l'Usine, St. Marcel, Hautmont (Nord), France.
1059. H. E. Riley, Burnside, St. Austell, Cornwall.
785. James Riley, Richmond Ironworks, Stockton-on-Tees.
1205. J. H. Riley, c/o Riley Bros., Stockton-on-Tees.
2023. Wm. Ripper, Hope, Nr. Sheffield.
943. H. L. Riseley, 72 Renfrew Road, Wallsend.
1842. A. Ritchie, c/o Messrs. MacDowall, Steven & Co., Ltd., 4 Upper Thames Street, London, E.C.
1843. G. M. Ritchie, Hæmatite Iron Co., Askham-in-Furness.
392. Geo. Ritchie, 9 Gordon Terrace, Shettleston.
1022. T. N. Ritson, Gas and Water Works, Kendal.
1500. Wm. L. Roach, Surveyor, Blaina, Mon.
1614. C. W. Roberts, Wollaston Hall, Stourbridge.
681. David E. Roberts, Dowlais Iron Works, Dowlais, Glam.
1639. James Roberts, The Leasowes, West Bromwich.
1997. M. G. Roberts, Briton Ferry.
+2048. Sir Wm. Roberts-Austen, K.C.B., F.R.S., 56 Princes Gate, South Kensington, London, N.W.
+ 571. W. C. Roberts, 18 Windsor Road, Forest Gate, London, E.
1467. David Robertson, 135 Waterloo Street, Glasgow.
2159. David Robertson, Merchant Venturers Technical College, Bristol.
1671. Duncan Robertson, Baldroma, Ibrox, Glasgow.
1198. Geo. T. Robertson, Taltal, Chili.
228. Graham Robertson, Merrylee Park, Cathcart.
292. John B. Robertson, Gas Works, Bathgate.
1474. L. J. Robertson, Nethertown, Palnackie, Dalbeattie, N.B.

644. Robert Robertson, 154 W. George Street, Glasgow.
2235. W. Robertson, Oakpark, Mount Vernon, Glasgow.
1178. M. Robin, 15 Clifford Street, Glasgow.
2251. A. W. Robinson, 879 Dorchester Street, Montreal, Canada.
641. John Robinson, Engineer's Office, New Dock Works, Middlesbrough
++2076. J. F. Robinson, Atlas Works, Springburn.
2346. Wm. Jas. Robinson, City Surveyor, Londonderry.
++2077. Hazleton R. Robson, 14 Royal Crescent, Glasgow.
787. R. Robson, 4 Rothwell Road, Gosforth, Newcastle-on-Tyne.
84. John Rochford, 4 Clarinda Park, West, Kingston, Co. Dublin.
++ 809. Anderson Rodger, jun., Glenpark, Port-Glasgow.
1096. Geo. Rodger, 34 Oak Hill Road, Sheffield.
1844. J. Pearce Roe, 30 St. Mary's Axe, London, E.C.
338. Geo. Wm. Roger, Shipbuilder, Irvine.
249. A. E. Rogers, Oaklands, Clonmel, Ireland.
++1066. T. B. Rogerson, East Thorne, Tollcross, Nr. Glasgow.
1845. Jas. Rollason, Broomfield Mills, Erdington, Nr. Birmingham.
1492. F. T. Rollin, 185 Penistone Road, Sheffield.
1478. John E. Rome, 6 Roseburn Place, Edinburgh.
404. Henry Ronald, Brighton House, Warwick Road, Birmingham.
++1659. J. M. Ronaldson, 44 Athole Gardens, Glasgow.
27. G. Rosenbusch, Royal Societies Club, St. James's Street, London, S.W.
47. E. A. Rosenheim, 1 Croxteth Road, Liverpool.
48. A. Ross, Gt. Northern Railway, King's Cross Station, London, N.
1338. Hugh Ross, Croxdale, Nr. Durham.
608. Jas. R. Ross, 7 Ashfield Gardens, Jordanhill.
832. J. M. Ross, Ardenlea, Lenzie.
782. Wm. Ross, 17 Pollok Gardens, Shawlands, Glasgow.
446. W. L. Rothwell, Sunny Mount, Redcliffe, Lancaster.
2267. E. Rotter, 12 St. David's Road, Southsea.
2217. Ernest E. Rouse, c/o Grindlay & Co., Parliament Street, Westminster, London, S.W.
958. O. M. Row, Westward Ho, Flixton, Lancs.
123. Frederick J. Rowan, 66 Kenmure Street, Pollokshields.
++ 276. J. Rowan, 22 Woodside Place, Glasgow.
2372. John A. Rowcliffe, Atlas Engineering Co., Manchester.
1346. B. R. Rowland, Climax Works, Reddish, Nr. Stockport.
1482. J. A. Rudd, 7 Hamilton Drive, Hillhead.
1480. M. Ruddle, Electric Light Station, Fleet Street, Dublin.
++ 896. Geo. Russell, Belmont, Uddingston.
1972. James Russell, Waverley, Uddingston.
215. Joseph Russell, Seafield, Ardrossan.
++ 28. R. Russell, White Stripe House, Newmains.
700. T. W. Russell, Prospect House, Newton Mearns, by Glasgow.
1207. A. Rutherford, Neptune Works, Birkenhead.
1426. Henry Rutherford, Aberlady.
1562. Walter Rutherford, English Electric Manufacturing Co.. Preston.
1670. Wm. Rutherford, Lindum House, Gateshead-on-Tyne.
820. J. E. Rycroft, 9 Oakroyd Ter., Manningham, Bradford, Yorkshire.
2364. E. F. Rydzewsky, Warsaw, Russia.
1930. Frederick C. Ryland, Exchange Buildings, Birmingham.

S

593. L. H. Sairle, Ramsden Dock Ext. Works, Barrow-in-Furness.
1248. Takashi Saito, 5 Vinery Villas, Park Rd., Regent Park, London, N.W.
1692. A. W. Sampson, Bonington, Bellahouston, Glasgow.

2299. Peter Samson, 56 Victoria Street, Westminster, London, S.W.
+2252. The Right Hon. Sir Bernhard Samuelson, Bart., 56 Prince's Gate, London, S.W.
865. M. Samuelson, Hessle, East Yorks.
707. A. G. Sanders, "The Birches," Grosvenor Place South, Cheltenham.
1615. John Sandford, 25 Netherton Road, St. Margarets, Twickenham.
912. C. Sangster, 3 Pittodrie Place, Aberdeen.
146. John W. Sankey, Claremont, Wolverhampton.
998. Kouji Satow, Tokio, Japan.
1616. Franz Sauer, 110 Cannon Street, London, E.C.
1173. F. H. Sawyer, 17 Eriswell Road, Worthing, Sussex.
1342. Alfred Saxon, 442 Ashton Old Road, Openshaw, Manchester.
1093. E. C. Sayer, 14 King Street, Ipswich.
1322. H. M. Sayers, 38 Chestnut Road, West Norwood, London, S.E.
++1275. Wm. B. Sayers, 189 St. Vincent Street, Glasgow.
1329. W. H. Sayers, 100 Bothwell Street, Glasgow.
1973. F. Scarf, Highfields, West Bromwich.
572. H. Scholey, c/o Messrs. Mather & Platt, 14 Victoria Street, London, S.W.
2172. Arthur E. Schute, 12 Clydeview, Partick.
29. C. Scott, Guide Bridge Iron Works, Nr. Manchester.
++2332. Chas. C. Scott, Greenock Foundry, Greenock.
1151. Chas. W. Scott, Dunarbuck, Bowling.
2116. Ernest K. Scott, Clun House, Surrey Street, Strand, London, W.C.
75. J. Scott, 49 Leazes Terrace, Newcastle-on-Tyne.
2343. James Scott, 14 Doune Terrace, Kelvinside, Glasgow.
1152. Jas. Scott, Strathclyde, Bowling.
450. J. Gray Scott, 27 Hamilton Park Terrace, Hillhead, Glasgow.
++2151. John Scott, C.B., Halkshill, Largs.
49. Ralph G. Scott, Monk Bridge Iron Works, Leeds.
1472. R. L. Scott, 4 Ardgowan Square, Greenock.
1847. Walter Scott, 30 Bellevue Crescent, Ayr.
1848. W. H. Scott, 46 Sandhill, Newcastle-on-Tyne.
2272. Geo. D. Scouler, Fleatham, St. Bees.
+2293. A. E. Seaton, Wilton House, Hull.
74. L. Serraillier, St. Stephen's House, Westminster, London, S.W
1468. A. G. Service, 27 St. Vincent Place, Glasgow.
2031. Wm. Sewell, Manor Office, North Bridge Street, Sunderland.
++2078. Prof. A. Humboldt Sexton, Glasgow and West of Scot. Technical College, Glasgow.
2309. E. Shane, Penrith.
791. D. Shanks, Newton Chambers, Cannon Street, Birmingham.
1849. J. R. Sharman, 2 St. Andrews' Square, Edinburgh.
1974. John Sharp, 1 Belsize Grove Mansions, London, N.W.
1980. John Sharp, 28 Burnbank Gardens, Glasgow.
1123. Sidney Sharpe, 34 Victoria Street, Westminster, London, S.W.
1321. John Shaw, Fern Lea, Ashton-on-Mersey, Cheshire.
1851. W. Shaw, Middlesbrough-on-Tees.
1270. Wm. B. Shaw, Roman Road, Bearsden.
1975. G. N. Shawcross, Lakelands, Horwich, Lancashire.
2264. R. Sheard, Spurr Inman & Co., Ltd., Wakefield.
1852. T. W. Sheffield, Trevelyan Buildings, Corporation St., Manchester.
1112. F. Sheldon, 3 Gordon Villas, Wells, Somerset.
174. Percy John Sheldon, The Chantry, Chelmsford.
1386. Geo. A. Shipman, 26 Filey Street, Sheffield.
1537. John F. Shone, "Fors," Meols Drive, Hoylake, Cheshire.
1559. Professor S. H. Short, 112 Cannon Street, London, E.C.
1334. Sydney Y. Shoubridge, Ravenswood, Forest Hill, London, S.E.
+ 374. Alex. Siemens, 12 Queen Anne's Gate, Westminster.

527. Harry Silvester, 36 Paradise Street, Birmingham.
2204. Harold H. Simmons, 78 Pepys Road, New Cross, London.
1853. W. Simons, Dowlais Iron Works, Dowlais.
1854. F. F. Simpson, Park Lane Iron Works, Oldbury, Nr. Birmingham.
526. H. Farr Simpson, County Surveyor, Wisbech St. Mary, Cambs.
1941. John G. Simpson, Hæmatite Iron Works, Harrington, Cumberland.
882. J. B. Simpson, Bradley Hall, Wylan-on-Tyne.
1939. R. Simpson, Corkickle, Whitehaven.
1195. Robert Simpson, 175 Hope Street, Glasgow.
1354. Walter Simpson, 446 Union Street, Aberdeen.
1012. Wm. Simpson, 15 Regent Quay, Aberdeen.
1998. D. T. Sims, jun., Neath, South Wales.
751. L. Skinner, 22 Ravensbourne Terrace, Southshields.
482. R. J. Skinner, Gas Works, Londonderry.
1125. John F. Smillie, Borough Surveyor's Office, Tynemouth.
1933. Samuel Smillie, 71 Lancefield Street, Glasgow.
1092. Alex. Smith, 16 Courthill, Bearsden, Nr. Glasgow.
1521. Charles F. Smith, 8 Dents Road, Wandsworth Com., London, S.W.
1000. Chas. E. Smith, Primrosehill, Old Aberdeen.
1938. F. Smith, Anaconda Works, Salford, Manchester.
1565. George E. Smith, 58 Mapperley Road, Nottingham.
576. G. H. Smith, The Gleddings, Halifax.
2230. H. O. Smith, 351 Renfrew Street, Glasgow.
675. H. W. Smith, Netherley, Pollokshields.
1413. James Smith, 6 Deveronside, Banff.
1977. James B. Smith, Diniskey, Cambuslang.
738. Jno. Smith, 112 High Street, Burton-on-Trent.
1976. John Smith, Ballinasloe.
1855. John L. Smith, Parkhurst, Eaglescliffe, R.S.O.
1018. J. P. G. Smith, Knatchbull Road, Willesden, London, N.W.
653. J. S. Smith, Harbour Engineer's Office, Aberdeen.
470. Peter Smith, 55 Osborne Road, Forest Gate, London, E.
2184. Sydney A. Smith, 1 Princes Street, Manchester.
1931. W. W. Smith, Locomotive Department, North Eastern Railway, Gateshead.
821. J. Smyth, Milltown, Banbridge.
1217. J. B. Sneddon, Calderbank House, Mid-Calder.
1549. R. M. Sneddon, 45 Whifflet Street, Coatbridge.
+ 758. Geo. J. Snelus, F.R.S., Ennerdale Hall, Frizington, Cumberland.
1188. Edw. Snowball, 10 Broomfield Terrace, Springburn, Glasgow.
1934. Arturo Sola, Alamedo de Mazarredo Y.Y., Bilbao.
1978. J. W. Somar, Stannington, Nr. Sheffield.
2198. S. S. Somers, Haywood Forge, Halesowen.
1689. Walter Somers, Belle Vue, Halesowen, Nr. Birmingham.
1550. Peter A. Somervail, 40 Athole Gardens, Glasgow.
1629. Thos. W. Sorby, Storshfield, Sheffield.
+ 2153. C. E. Spagnoletti, 2 Craven Terrace, Ealing.
2213. W .L. Spence, 19 Waterloo Street, Glasgow.
1937. Arthur Spencer, Phoenix Iron Works, Coatbridge.
285. Charles Spencer, Cleveland View, Middlesbrough.
1243. Henry B. Spencer, 48 Downshire Hill, Hampstead, London, N.W.
1936. John Spencer, Phoenix Iron Works, Coatbridge.
2278. T. H. Spencer, Globe Tube Works, Wednesbury.
757. A. Sproul, 34 Union Row, Aberdeen.
2106. Philip S. Stanhope, Midway, British Columbia.
659. H. Stansfield, Whalley, near Blackburn.
477. S. Stansfield, 195 Wood Bottom Terrace, Walsden, Todmorden, Yorks.
+ 1856. J. E. Stead, Laboratory and Assay Works, Middlesbrough.

380. W. R. Steele, c/o Delhi & London Bank, 123 Bishopgate Street, London, E.C.
1290. A. E. Stephen, Linthouse, Govan, Glasgow.
1446. F. J. Stephen, Linthouse, Govan.
++1126. John Steven, 9 Princess Terrace, Dowanhill.
1619. J. Wilson Steven, 9 Princes Terrace, Dowanhill, Glasgow.
606. Geo. Stevenson, Hawkhead, Paisley.
2308. S. O. Stevenson.
695. Wm. Stevenson, 25 Killermont Street, Glasgow.
1580. Wm. Stevenson, Bank Chambers, Sandhill, Newcastle-on-Tyne.
2199. Alex. W. Stewart, West Field, Dalmuir.
393. And. Stewart, 15 Leadside Road, Aberdeen.
1636. Charles R. Stewart, 7 Oakfield Terrace, Hillhead, Glasgow.
1110. D. Stewart, Blantyre Park, High Blantyre.
1461. D. Stewart, 14 Windsor Terrace, W., Glasgow.
1184. Geo. W. Stewart, 376 Great Western Road, Glasgow.
1023. Jas. Stewart, 13 Otterburn Road, Newcastle-on-Tyne.
+2255. Thos. Stewart, Harbour Works, Port Elizabeth, C.C.
2269. W. J. Stewart, Adelaide Street, Belfast.
1518. Wm. Stewart, Tillery Collieries, Abertillery, Mon.
551. Frank Stileman, 1 Victoria Street, London, S.W.
76. H. J. S. Stobart, Messrs. Chance Bros. & Co., Ltd., near Birmingham.
1585. Wilfrid Stokes, 32 Victoria Street, London, S.W.
2314. G. G. Stoney, 7 Roxburgh Place, Newcastle-on-Tyne.
259. W. E. Storey, Weston, Dale, Manchester.
2378. The Very Reverend Principal Story, The University, Glasgow.
713. P. C. Stormont, 76 Carden Place, Aberdeen.
1857. F. Storr, 19 The Groves, Chester.
1277. Adam Y. Storrar, 1 Bellefield Avenue, Magdalen Green, Dundee.
1979. Jacob Stottner, 122/4 Charing Cross Road, London, W.C.
788. Geo. Stow, Southdown Road, Shoreham, Sussex.
147. John Strachan, Craigisla, Penylan, Cardiff.
1940. Jas. M. Strain, 15 Kingsborough Gardens, Glasgow.
1. John Strain, Cassilis House, Ayrshire
389. Alex. G. Strathern, Izaville, Stepps.
1227. Jas. Stuart, 12 Broomhill Avenue, Partick.
776. J. T. Stuart, 2 Bowmont Terrace, Kelvinside.
2307. Wm. Stubbs, Borough and Water Engineer, Blackburn.
2202. Wm. E. Sumpner, Ainsdale, Moseley, Birmingham.
2313. M. Supplison, 29 Rue Boursault, Paris.
1285. R. T. Surtees, Town Surveyor, Hexham-on-Tyne.
594. Samuel Sutcliffe, Vron House, Mostyn, N. Wales.
2127. John R. Sutherland, 67 Hamilton Drive, Hillhead, Glasgow.
223. K. W. Sutherland, 18 Portland Terrace, Newcastle-on-Tyne
222. R. M. Sutherland, Solsgirth, Dollar.
1935. S. Sutherland, Arthurlie, Beech Avenue, Dumbreck.
928. H. A. Swan, Eastbrooke, Middlesbrough.
686. J. E. Swindlehurst, City Engineer, Coventry.
864. B. Sykes, Priors Lea, Broughton, Nr. Preston.
1932. James Syme, 8 Glenavon Terrace, Partick.
1642. M. H. Sykes, Borough Engineer, Stockton-on-Tees.
2241. R. C. Syson, Bearsden, Glasgow.

T

1626. W. A. Tait, 72a George Street, Edinburgh.
77. G. C. Taite, 25 Buckingham Gate, London, S.W.

1942. J. C. Taite, Metropolitan Bldgs., 63 Queen Victoria St., London, E.C.
2311. B. Talbot, Westminster Chambers, Leeds.
1519. William Tanner, County Surveyor, Newport, Monmouthshire.
+1946. A. Tannet-Walker, Hunslet, Leeds.
1858. John C. Tannett, Vulcan Works, Paisley.
840. T. Tatham, 104 Corporation Street, Manchester.
424. R. H. Taunton, Brook Vale, Witton, Birmingham.
1999. Richard H. Taunton, 10 Coleshill Street, Birmingham.
30. H. L. Taverner, 12 Mosley Street, Newcastle-on-Tyne.
336. James Tawse, Home Bank, Broughty Ferry.
473. Arthur Taylor, 18 Auriol Road, West Kensington, London, W.
1225. Benson Taylor, 22 Hayburn Crescent, Partickhill.
755. B. Taylor, 10 Derby Crescent, Kelvinside.
640. C. Percy Taylor, 68 Dover Road, Northfleet, Kent.
1081. F. C. Taylor, Gas Works House, Shanklin, Isle of Wight.
1683. G. Midgley Taylor, Messrs. J. Taylor, Sons & Santo Crimp, 27 Great George Street, Westminster, London, S.W.
199. C. L. Templer, 1 Bowden Terrace, Rugby.
187. John Tennent, Bredenhill, Bothwell.
599. F. R. Thackrah, 135 Rosary Road, Norwich.
2232. Edward Theisen, Baden-Baden, Germany.
2376. J. Thiry, 109 Victoria Street, Westminster.
514. J. Thom, 14 Charterhouse Square, London, E.C.
1569. E. H. Thomas, Oakhill, Aberdare, South Wales.
403. G. C. Thomas, Grand Junction Canal, 21 Surrey St., Strand, London, W.C.
1679. Hubert S. Thomas, Kayarina, Llanelly.
702. J. M. Thomas, Penryn, Cornwall.
1323. O. Thomas, Gas and Water Offices, Pentre, R.S.O., Glam.
839. R. Beaumont Thomas, Brynycaeran Castle, Llanelly, Carmarthen.
1568. W. Thomas, Oakhill, Aberdare, South Wales.
2051. Prof. G. R. Thompson, Yorkshire College, Leeds.
1358. J. G. Thompson, Collins Green, Earlstown, Lancashire.
752. N. A. Thompson, Clun House, Surrey Street, London, W.C.
+2305. Prof. Silvanus P. Thompson, Technical College, Finsbury, London, E.C.
2285. W. B. Thompson, Dundee.
591. A. M. Thomson, 121 Blackness Road, Dundee.
148. C. S. Thomson, 15 Forest Road, Loughborough, Leicestershire.
736. G. Thomson, 3 Woodburn Terrace, Edinburgh.
1309. Geo. C. Thomson, 53 Bedford Road, Rockferry, Birkenhead.
++1713. Gilbert Thomson, 164 Bath Street, Glasgow.
479. J. Thomson, jun., Harbour Engineer's Office, Dundee.
++2060. James M. Thomson, Glentower, Kelvinside, Glasgow.
2164. John Thomson, 3 Crown Terrace, Glasgow.
2124. John Thomson, North West Rivet, Boiler and Nut Factory, Ltd., 105 West George Street, Glasgow.
1576. Robert Thomson, 45 Dundonald Road, Kilmarnock.
++1107. R. H. B. Thomson, Govan Shipbuilding Yard, Glasgow.
643. Wm. Thomson, 20 Huntly Gardens, Glasgow.
++2079. Wallace Thorneycroft, 140 Hope Street, Glasgow.
1981. Edgar E. Thrupp, 39 Victoria Street, Westminster, London, S.W.
1948. B. H. Thwaite, Blast Furnace Power Syndicate, Ltd., 29 Gt. George Street, Westminster, London, S.W.
++ 803. E. G. Tidd, 2 Foremount Gardens, Dowanhill.
1253. I. A. Timmis, 2 Great George Street, Westminster, London, S.W.
546. Dr. Ed. Tinbeaux, Ingenieur des Ponts et Chaussees, 9 Bis Rue de Montet, Nancy, France.

922. R. Tindall, 167 Crown Street, Aberdeen.
1493. Vladimer Tinsheneski, Moguileff, Province of Podolio, Russia.
1943. V. F. J. Tlach, Messrs. Bohler Bros. & Co., Styrian Steel Works, Sheffield.
727. P. Tod, 28 Rawson Road, Seaforth, Liverpool.
1133. D. R. Todd, 39 Arcade Chambers, St. Mary's Gate, Manchester.
1944. J. P. Todd, 13 Chalsworth Street, Sunderland.
767. A. Tomiyama, 52 Hill Street, Garnethill.
1149. W. W. Topley, Croydon Com. Gas Co., Katherine St., Croydon.
683. Jno. W. Towle, 68 Lower Gardiner Street, Dublin.
2001. Harry B. Toy, Maiville, 41 Nicholls Street, West Bromwich.
1859. William Tozer, 13 Lawson Road, Sheffield.
2275. W. H. Travers, Egremont, Cheshire.
688. E. C. Trench, Alfreton, Derbyshire.
1352. R. S. Tresilian, 9 Upper Sackville Street, Dublin.
1860. Lt.-Colonel Trotter.
657. J. H. Troughton, Victoria House, Newmarket, Cambs.
1711. W. Tucker, Mayor of Christchurch.
111. James Tudhope, Willesden, Coatbridge.
+ 1705. J. H. T. Tudsbery, The Institution of Civil Engineers, Great George Street, Westminster, London.
1594. J. E. Tuit, 32 Victoria Street, Westminster, London.
1528. Arthur C. Turley, City Surveyor, Canterbury.
149. Alex. J. Turnbull, Myrtle Bank, Campbell Street, Greenock.
2038. Nicholas K. Turnbull, 2 Montague Terrace, Higher Broughton, Manchester.
550. Walter Alex. Turnbull, 5 Fern Avenue, Southwick, Sunderland.
++ 1356. W. G. Turnbull, Muriel Cottage, Uddingston.
2180. A. R. Turner, Winfield Mount, Meadow Road, Dumbarton, N.B.
1947. John H. Turner, 129 Trongate, Glasgow.
++ 1495. Thomas Turner, Broad Lea, Kilmarnock.
573. Thos. Twynam, Hawthorne House, Slaid Hill, Moortown, Nr. Leeds.

U

1648. W. R. Underhill, 18 Renfield Street, Glasgow.
997. Kisaburo Urano, Tokio, Japan.

V

1372. T. Vachell, Tridegar Chambers, Newport, Mon.
1470. David Vass, Gas Works, Airdrie.
1581. John Vaughan, Balaclava House, Dowlais.
1545. Wm. H. Vaughan, Lindum Lodge, 30 Brook Rd., Fallowfield, Manchester.
150. Henry R. Vereker, Skewdilla, Westport, Co. Mayo.
407. H. Vernon, Chepstow House, Oxford Road, Wakefield.
+ 1706. Prof. L. F. Vernon-Harcourt, 6 Queen Anne's Gate, Westminster, London, S.W.
447. H. Viney, 17 Eastlake Road, Cold Harbour Lane, Camberwell, London, S.E.
1861. John Vivian, 42 Lowther Street, Whitehaven.
78. M. Voisin, 282 Boulevard de Cauderan, Bordeaux, France.
1983. N. Vosnessensky, 21 Basseinaia, St. Petersburg, Russia.

W

2196. A. Waddell, Gas Works, Dunfermline.
2047. Forbes Waddell, Brook Street, Broughty-Ferry.
1211. Jas. Waddell, 15 Moray Place, Glasgow.
2183. James W. Wadsworth, Cleckheaton, Yorks.
985. Edw. B. Wain, Norton-in-the-Moors, Stoke-on-Trent.
2103. John W. Wainwright, Kyngstone, Park Road, Hale, Cheshire.
184. Archibald Walker, 6 Queen Gate, Dowanhill.
2024. Edwin R. Walker, 19 Roe Lane, Southport.
433. Fred Walker, Tyne Villa, New Road, Llanelly, S. Wales.
1310. H. Walker, 11 Oxford Terrace, Gateshead-on-Tyne.
2189. John Walker, Messrs. Robt. Stevenson & Co., Ld., Newcastle-on-Tyne.
1296. S. F. Walker, 2 Kensington Gardens Square, London, W.
+2132. William H. Walker, Cardarroch House, Airdrie.
535. Wm. L. Walker, Lea Hurst, Wrexham, N. Wales.
1292. Wm. Walker, jun., Springbank House, Dumbarton.
731. D. M. Wallace, 65 Union Street, Greenock.
1419. John Wallace, jun., 123 East Princes Street, Helensburgh.
1617. Joseph Wallace, Manahambri Road, Princestown, Trinidad
592. W. C. Wallace, Atlas Steel Works, Sheffield.
456. A. T. Walmisley, 9 Victoria Street, Westminster, London, S.W.
2134. Robert Mullineux Walmsley, 23 Hilldrop Road, London, N.
1357. Thos. Walshaw, Park Gate Iron Works, Rotherham.
1627. J. P. Walter, Consett Iron Co., Ltd., Blackhill, Co. Durham.
1335. Thos. Walton, Habergham Colliery, Burnley.
1254. W. E. Walton, Gas Office, Bishop Auckland.
1425. John Wamsley, Woodbank, Cram Road, Paisley.
432. Wm. Waplington, 1 Norton Tee, Clydach Vale, Llwynypid, R.S.O.
1264. John Ward, Linacre, Highfield Road, Derby.
1715. John C. A. Ward, 75 Waterloo Street, Glasgow.
1862. Thomas A. Ward, Fitzalen Chambers, Sheffield.
1551. Henry W. Warde, Oakbank, Crookston, Renfrewshire.
773. W. C. Warden, 4 Kensington Gate, Kelvinside, Glasgow.
545. J. W. Wardle, Court House, Longton, Staffs.
335. Francis J. Waring, 2 Delahay Street, Westminster, London, S.W.
278. H. Waring, Shanagarry, Milltown, Dublin.
1990. Alfred Wm. Warner, Corn Exchange Iron Works, Lion St., Ipswich.
1950. W. Warner, Westwood, Clumber Road, Nottingham.
1228. John Alex. Warren, 74 Balshagray Avenue, Partick.
1229. Robert George Warren, 29 Scott Street, Garnethill.
1060. R. Warriner, 129 Embleton Road, Lewisham, London, S.E.
1657. Major Wm. Waterhouse, Church Gresley, Nr. Burton-on-Trent.
++1046. Prof. W. H. Watkinson, The Pines, Crookston.
1394. Geo. Watson, 50 W. Kensington Mansions, London, W.
627. Jas. F. Watson, 15 Shaw Lane, Headingley, Leeds.
1013. John Watson, 11 Wilson Patten Street, Warrington.
1644. J. Stanley Watson, 7 Ashmount, Sheffield.
2025. Wm. Watson, Burgh Surveyor, St. Andrews.
661. James Watt, 17 Richmond Terrace, Aberdeen.
1190. Thos. H. Watt, 53 Bothwell Street, Glasgow.
1128. A. Weatherilt, Denton's Green Lane, St. Helens, Lancashire.
+151. Wm. Weaver, The Limes, Holland Park Gardens, Kensington, W.
648. Henry Webb, Irwell Forge and Rolling Mills, Bury, Lancs.
419. James A. Webb, Stanmore, Middlesex.
516. Tho. Henry Webb, 31 Storer Road, Loughboro', Leicestershire.
1313. W. H. Webb, 2 Boundary Road, Birkenhead.

1417. J. J. Webster, 39 Victoria St., Westminster, London, S.W.
689. A. H. Weddell, Park Villa, Uddingston.
780. Jas. Weddell, Park Villa, Uddingston.
1863. Herman Wedekind, 158 Fenchurch Street, London, E.C.
1232. Arthur D. Wedgwood, Alexandria House, Alexandria.
1283. A. Wedgwood, Dennystown Forge, Dumbarton.
494. J. G. Weeks, Bedlington, R.S.O., Northumberland.
621. R. W. Weekes, 73 Elliscombe Road, Charlton, London, S.1 .
+ 79. Prof. R. L. Weighton, Durham Coll. of Science, Newcastle-on-Tyne.
++ 1130. Jas. Weir, 72 St. Andrews Drive, Pollokshields.
857. Wm. Weir, 190 Nithsdale Road, Pollokshields.
1129. Wm. Weir, Holm Foundry, Cathcart.
1276. Chas. F. H. Weiss, 14 Well Walk, Hampstead, London, N.W.
2258. A. E. Welby, Farndon, Newark-on-Trent.
359. Henry M. Wells, Imperial Oil Works, Deansgate, Manchester.
980. Geo. M. Welsh, 3 Princes Gardens, Dowanhill, Glasgow.
978. James Welsh, 3 Princes Gardens, Dowanhill, Glasgow.
979. Thomas M. Welsh, 3 Princes Gardens, Dowanhill, Glasgow.
327. Wm. S. Welton, Elm Road, Wembley, Middlesex.
1241. Joseph A. Wesley, Fern Villa, Hamilton Road, Lincoln.
953. E. W. West, Fairfield, Govan.
+ 2082. H. H. West, 5 Castle Street, Liverpool.
+ 2026. John West, Barfield, West Didsbury, Manchester.
885. Lt.-Col. J. H. Western, Broadway Chambers, Westminster, S.W.
2371. John Westgarth, Engineer, Middlesborough.
1435. Alf. Whalley, Ashville, Helsby, Warrington.
197. W. H. Wheeler, Wyncote, Boston, Lincolnshire.
1628. C. Whensa-Nicholl, Armiston Coal Co., Ltd., Gorebridge.
399. A. J. While, Whinsfield, Barrow-in-Furness.
426. J. M. While, Whinsfield, Barrow-in-Furness.
1534. Jas. Whimster, Armagh, Ireland.
1304. Geo. C. Whitbread, Carlton, Nottingham.
1544. Richard Whitbread, Carlton, Nottingham.
1864. Henry White, Derwent, Goldtops, Newport, Mon.
2110. Henry J. White, 21 Staverton Road, Oxford.
2182. John N. White, Stonecliffe, Stalybridge.
2123. J. Walwyn White, Old Public Hall, Widnes, Lancs.
253. R. White, 3 Victoria Street, London, S.W.
1167. Thos. Whitehead, 186 Gt. Clowes Street, Broughton, Manchester.
1986. Andrew H. Whitelaw, 74 Dundonald Road, Kilmarnock.
1955. R. Cyril V. Whitfield, 5 Albert Terrace, Middlesbrough.
547. Chas. H. Whiting, 42 Avenue Henri Martin, Paris.
2370. E. B. Whitman, Wallbrooke, Baltimore, Maryland, U.S.A.
50. J. H. Whittle, 11 Hamilton Road, Ealing.
2350. Jos. M. Whitwell, Saltburn by the Sea, Yorkshire.
+ 1865. William Whitwell, Stockton Iron Works, Thornaby-on-Tees.
+ 2338. Peter Whyte, Leith Docks, Leith.
+ 1311. J. H. Wicksteed, Weetwood Croft, Leeds.
1954. F. H. Wigham, Lake Lodge, Stanley, Wakefield.
152. John R. Wigham, 33 Capel Street, Dublin.
1985. Wm. D. Wight, Cory Bros. & Co., Ltd., Pentre, R.S.O., Glam.
716. P. F. C. Wilcox, 15 Norfolk Street, Sunderland.
1687. F. Wilkinson, Director of Technical School, Bolton.
1866. Thomas Wilkinson, Tay Lodge, Pitsmoor, Sheffield.
2226. W. F. Wilkinson, Roscoth Lawn, Harrow
2087. A. M. Willcox, Amberley House, Norfolk Street, London, W.C.
530. Clifford G. Williams, Stanley House, Wake Green, Moseley, B'ham.
1957. Dan Williams, Mining Engineer, Llanelly.

1632. H. B. Williams, 100 Gray Street, Workington, Cumberland.
1171. H. J. C. Williams, Coed Celyn, Dolgelley, N. Wales.
1635. Lewis N. Williams, Caecoed, Aberdare, S. Wales.
1291. L. W. Williams, 3 Park Terrace, Crosshill.
734. O. R. Williams, The Linn, Cathcart.
2369. R. B. Williams, Jun., 315 South Albany Street, Ithaca, New York.
1643. Alex. Williamson, 67 Esplanade, Greenock.
1867. Alexander Williamson, Craigbarnet, Greenock.
1183. J. Williamson, Arden Ville, Balgray Hill, Springburn, Glasgow.
879. Jas. Williamson, 59 Octavia Terrace, Greenock.
112. Richard Williamson, South Lodge, Cockermouth.
1497. Robert Williamson, Ormidale, Malpas, Newport, Mon.
798. Edw. Willis, 293 Willesden Lane, Willesden Green, London, N.W.
342. Alex. Wilson, Dawsholm Gas Works, Maryhill.
31. A. F. Wilson, Burnbrae, Balfron, Stirlingshire.
267. A. H. Wilson, 2 Albyn Terrace, Aberdeen.
175. Archd. Wilson, Glenleven, Alexandria, Dumbartonshire.
294. Arthur H. Wilson, 4 St. John's Terrace, Glasgow.
2297. C. Wilson, Oakbank, Hammersmith.
2270. Ernest Wilson, Clarence House, South Parade, Skegness, Lincoln.
1543. H. R. Wilson, 28 Victoria Street, London, S.W .
436. James Wilson, Queen's Hotel, Rothesay.
2006. James Wilson, Hartlepool Engine Works, Hartlepool.
1146. J. R. R. Wilson, 182 Chapelton Road, Leeds.
1667. Wm. H. Wilson, 34 Maxwell Drive, Pollokshields, Glasgow .
669. Wm. Wilson, Burnbank House, Coatbridge.
598. W. R. Wilson, Thorncliff, Greenock.
293. W. S. Wilson, 4 St. John's Terrace, Glasgow.
181. Thos. J. Winn, 44 Hilldrop Crescent, Camden Rd., London, N.
346. Douglas Winning, Municipal Buildings, Broughty Ferry.
845. W. G. Winterburn, General Manager, Geo. Fenwick & Co., Ltd., Engineers and Shipbuilders, Hong Kong, China.
233. F. Wiswall, 10 Stanley Villas, Runcorn.
760. H. Withy, Middleton Shipyard, Hartlepool.
797. J. J. Wolff, Ashurst, Sydenham, London, S.E.
1649. Arthur P. Wood, Spring Bank, Whitefield Foad,Ashton-on-Mersey, Cheshire.
774. D. Wood, Hastings Avenue, Chorlton-cum-Hardy.
2174. Edward Wood, 27 Brunswick Terrace, Harrogate.
80. E. M. Wood, 3 Victoria Street, Westminster, London.
1624. Frederick J .Wood, County Surveyor, County Hall, Lewis, Sussex.
1952. Jno. Wood, Barley Brook Foundry, Wigan.
1016. Thos. Wood, Barley Brook Foundry, Wigan.
1987. Walter Wood, Philadelphia, U.S.A.
1953. W. K. Wood, 153 Queen Street, Glasgow.
2095. Wm. Wood, Ardgowan, Kilmalcolm.
786. Wm. E. Wood, 46 Church Street, Accrington.
1553. J. Cowan Woodburn, 18 Beechwood Drive, Jordanhill, Glasgow.
619. Wm. H. Woods, Southfield, Hale, Cheshire.
1951. J. H. Woodward, Urban District Council, Skipton.
153. Dr. Robert L. Woolcombe, 14 Waterloo Road, Dublin.
549. Joseph Woolf, jun., 32 Victoria Street, London, S.W.
517. R. J. Worth, East View House, Seaton, Carew.
+ 1707. Edgar Worthington, The Inst. of Mechanical Engineers, Storey's Gate, London, S.W.
1538. W. B. Worthington, 2 Wilton Polygon, Cheetham Hill, Manchester.
1956. J. D. Wragg, Swadlincote, Burton-on-Trent.
1958. G. H. Wraith, Tudhoe Iron Works, Spennymoor.

1656. H. O. Wraith, 44 Croft Avenue, Sunderland.
2117. Romulus P. Wray, 33 Culchith Lane, Newton Heath, Manchester
2012. T. H. Roberts Wray, The British Schuckert Electric Co., Ltd.
533. Isaac H. Wright, 15 Gladstone Street, Keighley, Yorks.
1320. James Wright, 181 Queen Victoria Street, London, E.C.
1189. John Wright, 40 Leadenhall Street, London, E.C.
229. Robert Wright, Lloyds Office, 342 Argyle Street, Glasgow.
1090. Thomas Wright, 2 Berkeley Terrace, Glasgow.
1685. Thomas Wright, c/o Siemens, Bros., & Co., Ltd., Woolwich.
+ 900. Sir Thomas Wrightson, Mashona Hall, Darlington.
154. H. H. Wyatt, 2 Crosby Square, London, E.C.
1949. C. D. Wybron, Symabelle, Landsdowne Road, Bournemouth.
188. Alexander Wylie, Kirkfield, Johnstone.
396. John Wylie, Jun., Oswald Villa, Coatbridge.
++ 220. Wm. Wylie, Clifton Iron Works, Coatbridge.

Y

2052. T. H. Yabbicom, City Engineer, 63 Queen's Square, Bristol.
1554. F. A. Yerbury, Oaklea, Lenzie.
1486. C. Y. Young, W. Parkweg 9, Amsterdam, Holland.
1216. G. F. Young, 35 Woodside Quad., Glasgow.
++ 1078. John D. Young, 6 Carlton Terrace, Glasgow.
1288. John Young, Cross Lynne, Bearsden.
1477. John Young, 20 Chalmers Road, Ayr.
1868. John Young, 42 Bath Street, Glasgow.
++ 2083. John Young, 88 Renfield Street, Glasgow.
++ 1439. Thos. Young, Rowington, Whittingham Drive, Kelvinside, Glasgow.
604. Wm. Young, Walton Bank, Cambuslang.
654. A. S. Younger, 8 Walmer Crescent, Glasgow, S.S.
611. John Younger, Birch Bank, 88 Albert Road, Crosshill.

Z

889. H. Zweig, Director of Naval Construction, Pola, Austria.

INDEX.

LIST OF PAPERS.

With Authors' Names and Pages for Abstracts

PAPERS IN SECTION IV.—NAVAL ARCHITECTURE AND MARINE ENGINEERING.

PAPERS IN SECTION V.—IRON AND STEEL.

PAPERS IN SECTION VI.—MINING.

SECTION VII.—MUNICIPAL.

LIST OF AUTHORS OF PAPERS.

With Titles of Papers and Pages for Abstracts.

ERRATA.

Page 2, line 4, *for* first paragraph *read*, "The Members of this Committee are distinguished by the sign + or ++ placed opposite their names in the list of members."

Page 146, line 5 from top, *for* Tuesday 8rd *read* Tuesday 3rd.

Page 217, line 20 from top, *for* Fields *read* Fells.

Page 237, line 2 from bottom, *for* 4,602 *read* 4·602.

Page 240, line 1, *for* marble *read* marl.